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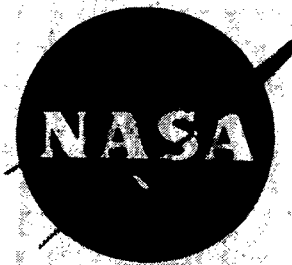
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**FINAL REPORT**

**DEFINITION STUDY FOR AN EXTENDED MANNED TEST  
OF A REGENERATIVE LIFE SUPPORT SYSTEM**

November 1971

**CASE FILE  
COPY**



Prepared under Contract No. NAS1-10790  
by the Biotechnology and Power Department  
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Huntington Beach, California

For

**Langley Research Center**

**NATIONAL AERONAUTICS and SPACE ADMINISTRATION**

## FOREWORD

A Definition Study for Extended Manned Testing of a Regenerative Life Support System has been conducted by the Biotechnology and Power Department of the McDonnell Douglas Astronautics Company (MDAC), Huntington Beach, California, under Contract NAS1-10790. This project was performed for the NASA-Langley Research Center under the direction of Mr. C. W. McKee of the Space Systems Division.

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The results of this study are presented in the following reports:

NASA CR-112000, (MDC G2624) Final Report

NASA CR-111999, (MDC G2625) Preliminary Test Plan

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## Section 1

### INTRODUCTION

The performance of future long-duration manned space flights will require an automated, fully integrated environmental control and life support system which will perform efficiently, with minimum use of expendables and of crew time for operation, maintenance, and repair. Development of this system requires the comparative evaluation of alternate processes and equipment for performing the required functions. Some of the information required for this evaluation is available from subsystem performance data obtained during bench tests on prototype units. Manned tests of integrated life support systems also are required to obtain data on subsystem interaction, to evaluate the man/system interface and to provide a verification of the efficiency of the system to support man in an operational environment. Experience on previous manned tests has shown that areas of weakness are frequently exposed which guide the subsequent development and design effort.

This report defines a preferred approach for future extended manned tests of integrated life support systems. Much of the rationale is based upon a review of previous operational manned tests such as the 90-day test conducted by McDonnell Douglas Astronautics Company for NASA-LaRC in 1970. The test philosophy is based upon the economic advantages to be gained from closed system testing of new, advanced equipment while in the prototype stage, thus guiding the system design and component selection and providing a higher level of confidence before the expense of producing flight type hardware has been incurred.

In addition to this report, the study of extended manned testing has produced a Preliminary Test Plan NASA CR-111999, which is presented in an accompanying volume. This is based upon the Test Plan and Procedure from the 90-day manned test, and incorporated the changes made as a result of this study. It was prepared to cover specifically the Phase A test but is generally applicable



to future manned tests. It includes a Design Requirements Specification as an appendix which is intended for application to the suppliers of advanced subsystems as well as to the test contractor in order to assist in developing an integrated life support system capable of performing efficiently and reliably during extended manned tests. For the purposes of this report, an advanced subsystem is defined as a subsystem or unit of improved design of a type which has not undergone previous extended manned testing.

## Section 2

### SUMMARY

The study described in this report has resulted in the definition of a program to perform extended ground based manned tests of regenerative life support systems. The general objective of these tests is to evaluate prototypes of advanced life support systems under operational, integrated conditions, thus providing data that is essential in the design of efficient environmental control and life support systems for use in future long duration space missions.

In addition to equipment evaluations, the study has defined the requirements for test operations to provide a simulation of an orbiting space laboratory so that crew activities and man/system interfaces are realistically similar to those that would actually occur. Experience has indicated that, without this realism, loads applied to life support subsystems do not approximate those that will be encountered in space operations.

The study has identified sufficient need to perform two extended manned tests in sequence, on the basis of advanced subsystems that are currently under development and will be available for evaluation in time periods of mid-1972 and mid-1973. It is expected that additional equipment from future developments will result in requirements to run subsequent tests, following the two described herein.

Table 1 describes the salient features of the Phase A and Phase B programs. These tests feature the use of proven backup equipment to ensure the generally successful evaluation of the advanced subsystems in spite of the occasional malfunction that can be expected due to their relatively early state of development. An adequate pre-test all-systems checkout period is provided to minimize equipment problems during extended testing and to familiarize all crew and operating staff members with test equipment and procedures.

Table 1

EXTENDED MANNED TEST FEATURES

<u>Phase A Test</u>	<u>Phase B Test</u>
Sea Level Pressure	Sea Level Pressure
4-Man Crew	4 or 6 Man Crew (6 man crew requires enlarged chamber)
No pass in or out	No pass in or out
Advanced subsystems plus proven backups for most functions	Two sets of advanced subsystems
Water coolant loop inside cabin	Water coolant loop inside cabin
Coolanol 35 hot and cold loops required if Molecular Sieve unit is backup	Electric power, simulated solar collector or radioisotopes may be used if process heat is required
LSS venting minimized	LSS venting may be eliminated if suitable advanced subsystems are available
Computerized Crew Activity Schedules	Computerized Crew and Operating Staff Activity Schedules
Mixed-sex crew if equipment availability permits	Mixed-sex crew
Thorough all systems pretest checkout plus 100-hours continuous manned run before test start	Thorough all-systems pretest checkout plus 100-hour continuous manned run before test start
Integrated data management, monitor, and alarm system	Same plus life support system automation

One of the major objectives of the planning is to eliminate wherever possible the requirement for venting or transfer of material outside the test chamber. An on-board laboratory has been defined which will provide the means necessary for monitoring to certify potability of reclaimed water, to ensure health and safety of the crew, and to provide the necessary documentation of test results.

The requirements for medical and man/systems implementation have been defined, to provide improved data on the effects of confinement on the crew, and their microbiological environment, and to evaluate improved habitability features such as an on-board shower, improved recreational facilities and enhanced decor of the living quarters.

To provide documentation of test results, as well as on-the-spot guidance to test operations, a data management system has been defined which utilizes an on-line computer for data collection and display as well as automatic centralized monitor and alarm functions. Demonstration of system automation concepts by central computer control is also feasible, and several potential applications have been described.

In addition to the basic objective of supporting an extended manned test for evaluation of advanced life support subsystems, a number of supplementary investigations have been outlined. These cover evaluation of equipment that are not part of the life support system, or performing biomedical and behavioral investigations. Such investigations can be economically performed during an extended manned test, where there is not usually sufficient justification for organizing a separate investigation, and also provides the operational realism that is important in obtaining a valid simulation.

### Section 3

#### TECHNICAL DISCUSSION

The planning of an extended manned test of an advanced regenerative life support system emphasizes the evaluation of the interactions between prototype life support equipment during a simulation of a space mission. Such a test must include as accurately simulated operational mission conditions as possible because experience has shown that there is no other way to be sure that realistic loads are applied to the Life Support System, either in average or in transient magnitudes. Such a test has the further advantage that many "piggyback" evaluations can be conducted that would be impossible or economically impractical as separate investigations.

The study reported herein has planned such a test, defining test program objectives, operational requirements, equipment to be evaluated, and test facilities that will be needed. The requirement for medical, microbiological, and crew integration activities necessary to support such a test are determined, and subjects for potential special studies have been defined. The alternatives considered have been discussed and the rationale used in making selections is described. This information is included in the following discussion.

#### 3.1 OBJECTIVES FOR AN EXTENDED MANNED TEST PROGRAM

The general objective of performing an extended manned test of a regenerative life support system is to evaluate prototype equipment and processes in an integrated system and to perform such auxiliary studies that will assist in obtaining this evaluation, or that may economically be performed concurrently, thus enhancing the value of the program. In meeting this general objective, a list of detail objectives have been established. These objectives, in the approximate order of priority, are included in the following list:

- 
- A. Expand the technology for advanced regenerative life support systems and obtain data on performance, operating characteristics, maintainability, and subsystem interactions.

- B. Investigate and evaluate concepts and techniques of systems automation in the areas of monitor and alarm, fault isolation, automatic checkout, and parametric feed back control which may be applied to life support systems.
- C. Develop techniques for monitoring the status of equipment, health and morale within the vehicle, minimizing the requirement for outside laboratory support and eliminating the need, whenever possible, for passing out samples from the chamber.
- D. Perform selected earth-orbital experiments and evaluate onboard and external support requirements.
- D. Perform mission planning and provide the necessary equipment and procedures to establish crew task requirements that are realistically representative of in-flight experiments and operational needs, to evaluate the man-systems interfaces, to properly assess the equipment capabilities in supporting the crew, and to maintain the crew morale by assigning meaningful work.
- F. Evaluate the effects of the closed environment on the physiological and psychological status of the crew.
- G. Obtain data and trends on chemical and microbial characteristics in the closed environment.

### 3.2 MANNED TEST OPERATIONAL REQUIREMENTS

In planning an extended manned testing program in accordance with the objectives stated in Section 3.1 it has been necessary to consider the availability of advanced, prototype equipment; the operational constraints imposed by manned testing safety requirements; and the relationship between benefits and cost as related to test duration and frequency. These result in a program plan, considering the duration and frequency of future tests, and an operational plan in which the preparation for the test, the requirement for program reviews, and the methods to be used for scheduling crew activities during the test is defined.

As shown in Section 3.3.1., there are two groups of prototype life support subsystems which will be available for manned testing, in terms of chronological development status. One group will become available about mid-1972 and may be effectively tested later in the year, using presently existing equipment for backup to insure continuity of testing without risk of failure due to the developmental nature of the advanced subsystems. The second group, representing further improvements in the efficiency of regenerable subsystems, will be available approximately mid-1973. This suggests planning two extended manned tests for full evaluation of equipment presently in process. The first, or Phase A, test could occur late in 1972; the second, or Phase B, late in 1973. The second phase can normally be expected to include improved models of the advanced subsystems from Phase A as backup units to the new prototypes. In some cases there appears to be two or more sets of alternate methods which should be evaluated during Phase B. One example is the upgraded Sabatier reactor and Bosch reactor for CO<sub>2</sub> reduction. Of course, these tests as well as other developments in regenerative life support, are expected to suggest improvements in system design and operation which will justify further tests following Phase B. It is not considered to be appropriate to attempt to define these follow-on tests at the present time since they are dependent upon the next several years of development effort and program planning.

### 3.2.1 Test Duration and Frequency

Criteria for establishing test duration can be developed from experience gained during previous manned tests having similar objectives. One such test was for 90 days, completed by MDAC under NASA Contract NAS1-8997 in 1970 (Reference 1).

Review of the data on equipment evaluation from the 90-day test shows that the first few weeks were characterized by a high level of maintenance and repair activities. Equipment down-time interfered with attainment of sufficient stable system operation during this period to define performance. Reliability gradually improved through day 40, when a reasonably low level of maintenance and repair activity was reached and maintained for the balance of the test. Experience with system operation and performance measurements indicated that as much as 5 to 7 days of stable operation was required to obtain stable

data in some cases, such as the water recovery subsystem, in which a significant variation in intermediate storage of water could occur, or the atmosphere purification and control, where long term transients in consumption/generation rates of oxygen or trace gases were common.

Analysis of factors behind this test experience indicated that:

1. Many early failures were "green failures" due to "weak-link" components or monitoring instrumentation that could have been picked up by adequate pre-test checkout. However, late arrival of several advanced subsystems required major emphasis on installation of equipment and crew training during the 6-weeks preceding the test start. This in addition to slips in availability of full data management capability prevented adequate pre-test equipment checkout.
2. Much time was spent during first 30 days in learning integrated system operating characteristics which should have occurred during the pre-test checkout phase that was inadequate for above reasons. This was particularly true of many operating staff members who were specialists on individual subsystem but very poorly cross-trained on the balance of the system and related operating procedures.

In planning for an efficiently performed test, it is possible to improve pre-test procedures on the basis of these findings and achieve a substantial reduction in the early "break-in" period. Thus the expense of continuous manned testing can be reduced if an adequate pre-test checkout period is provided. After all equipment is installed, an all-systems checkout period of two weeks (days only) is recommended for final cross training, and learning operational characteristics as well as verifying proper integrated operation. This should be followed by a continuous manned 100-hour test for final verification of procedures and insurance against unexpected trace contaminant buildup, etc.

Assuming this checkout period is provided, and that the potential for failure is the same for the Phase A system as the 90-Day test system, it appears that adequate pre-test checkout can replace approximately the first 30



days of early test experience of the 90-day test. There is, therefore, a high probability that reliable equipment operation and stable conditions will allow the required data to be collected during a test of 4 weeks duration.

Availability of adequately trained and qualified operating staff is a serious problem during continuous manned testing. During the 90-day test, operating staff members worked 21 continuous days then took seven days off. This required 4 complete teams of four men each, excluding the medical monitors, supporting staff (on a normal daytime work shift) and program management. This was an acceptable schedule to the staff and little signs of fatigue were apparent toward the end of one of these tours. The biggest problem was in getting teams "up to speed" regarding events of the previous week when they came back on duty.

An efficient schedule for the operating staff would feature a continuous tour for the entire test duration, if possible. It appears that a continuous tour of 4 weeks followed by adequate time off is feasible.

On the basis of this experience it is recommended that a test duration of 4 weeks be selected for Phase A. This gives high probability of meeting test objectives. It also allows operating economics, with no change of operating personnel mid-test, in that a 20-25% reduction in staffing and staff training is possible and no indoctrination of returning personnel is required.

In consideration of test objectives and available equipment for the Phase B test, life support system studies have identified two basic sets of advanced subsystems for most functions for Phase B. In some cases it appears logical to use one advanced subsystem for a period of time, then switch over to the alternate. Evaluation of several subsystems in integrated operating mode is, therefore, possible. An example is the use of both the Bosch and Sabatier system in conjunction with the Hydrogen Depolarized CO<sub>2</sub> concentrator. These two CO<sub>2</sub> reduction systems have significant differences in hydrogen flow requirements which have an impact on the HDC depolarizing flow rate. Evaluation under both

operating conditions is important. Similarly, there may be some Shuttle-related units, such as the Regenerable Dessicant and CO<sub>2</sub> Removal unit, which require evaluation over a 7-day period and influence integrated system operation during the period.

For regenerable subsystem evaluation, it is recommended that a 4-week minimum continuous operating period be established, on a basis similar to the Phase A test. A duration of the Phase B test of 8 - 9 weeks is therefore recommended in order to provide for evaluation of duplicated functions and, possibly, Shuttle-related non-regenerable equipment.

### 3.2.2 Functional Sequence of Events

Analysis of the program requirements shows that the preparation for, execution, and documentation of an extended manned test requires the performance of the following tasks:

1. Prepare Test Plan and Procedure

This task will start from the Preliminary Test Plan NASA CR-111999 prepared during the present study. This will be updated and reissued soon after ATP for the test program. Then, in accordance with the change procedure established, it will be elaborated upon as program definition proceeds. A final pretest release will be made just before test start.

2. Plan Add-On Experiment

The incorporation of well planned experiments adds a great deal to the value of the extended manned test. This task accomplishes the necessary planning and coordination.

3. Simulator and Facility Improvements

Necessary modifications to the simulator and supporting facilities will be made to meet contractual requirements.

4. Prepare Backup Life Support Subsystems

Backup life support subsystems will be prepared to integrate with new advanced subsystems, and then installed into the simulator for checkout.

5. Advanced Subsystems

Advanced subsystems will normally be procured by NASA from various contractors and supplied as GFE to the test contractor. This task provides for coordination and integration of these subsystems and assembly into the simulator.

6. Instrumentation and Data Management

Design, assemble, and checkout the necessary equipment to measure equipment parameters and document performance.

7. System Integration

An all-systems checkout will be conducted as a final proof test of the equipment, for training of the test crew, and for cross-training of the operating staff to improve the general knowledge of all aspects of the system performance characteristics. This is planned to require two complete weeks of operation but is planned over a 4 calendar week period to allow initial troubleshooting.

8. Crew Integration

This task includes preparation of recruiting brochures, receiving and reviewing applications, screening and selection of candidate crewmen, training program, obtaining pretest baseline medical and physiological data, participation in the system integration tests (Task 7), a 100-hour continuous manned checkout test, the extended manned test, and post-test debriefing and obtaining post-test baseline data.

9. 100-Hour All Systems Checkout Test

A final checkout of all equipment, crew, and operating staff will be conducted during a 100-hour all systems checkout test under continuous manned operating conditions.

10. Extended Manned Test

Conduct the extended manned test.

11. Safety Reviews

As in the 90-day test, it is expected that a two-level review will be conducted as follows: the contractor will appoint an Operational Readiness Inspection Committee (ORIC) to provide continuous surveillance of all safety aspects of the program and the NASA will constitute an Operational Readiness Review (ORR) Committee which will periodically review program progress, including a final review just prior to test start.

12. Data Reduction and Analysis

13. Presentation of Results and Preparation of Final Report

14. Publish Test Report

This task breakdown is very similar to that of the 90-Day Test but features two significant changes. The unmanned checkout test has been deleted in accordance with conclusions presented in the Final Test Plan and Procedure (Reference 2) since the equipment is not normally designed to operate without the presence of an operator and since it was felt that additional systems checkout and crew training would produce more meaningful results. Also, in planning the ORR Committee activities, a detail review was provided just prior to the 100-hour continuous manned checkout test, and final approval for start of the extended test is expected to require only a brief review of checkout test results rather than a complete, second review by the full committee. This change will allow reduction of elapsed time between the

checkout test and start of the extended test, and will be feasible only if the more extensive System Integration period (Task 7) has fully demonstrated equipment readiness.

Figure 1 shows the time sequence of events required to implement the above tasks for the Phase A test. It can be seen that the test can start in 39 weeks after contract award, with the final report publication in 66 weeks. This schedule is contingent upon availability of advanced subsystems as required for installation starting the 23rd week after ATP.

Figure 2 shows a similar time sequence for the Phase B test. This schedule assumes an ATP for Phase B at the completion of the Phase A test (43 weeks after Phase A ATP) and provides a continuity of effort into the Phase B program. The same task breakdown is appropriate although, if two sets of advanced subsystems are provided as GFE, as recommended in this study, no effort will be required under Task 4 (Backup Life Support System). In accordance with this plan, the Phase B test can start 48 weeks after completion of the Phase A test, and the final test documentation will require 80 weeks after completion of the Phase A test. The total program duration, for Phase A and B, is therefore 123 weeks.

### 3.2.3 Crew Activity Scheduling

The performance of future long-duration manned space flight will not only require automated, fully integrated environmental control and life support systems, but will also require a capability for autonomous crew operations. To satisfy the latter requirement, the crew needs a capability for mission planning and activity scheduling. Consideration must be given to such items as work/rest cycle variations, equipment sharing, time-position event scheduling, number of crewmen available for duty, crew skill proficiency effects, scheduling conflicts, and requirements for team tasks. The planning, scheduling, display, and rescheduling techniques may be developed and feasibility demonstrated during the forthcoming series of ground simulations.

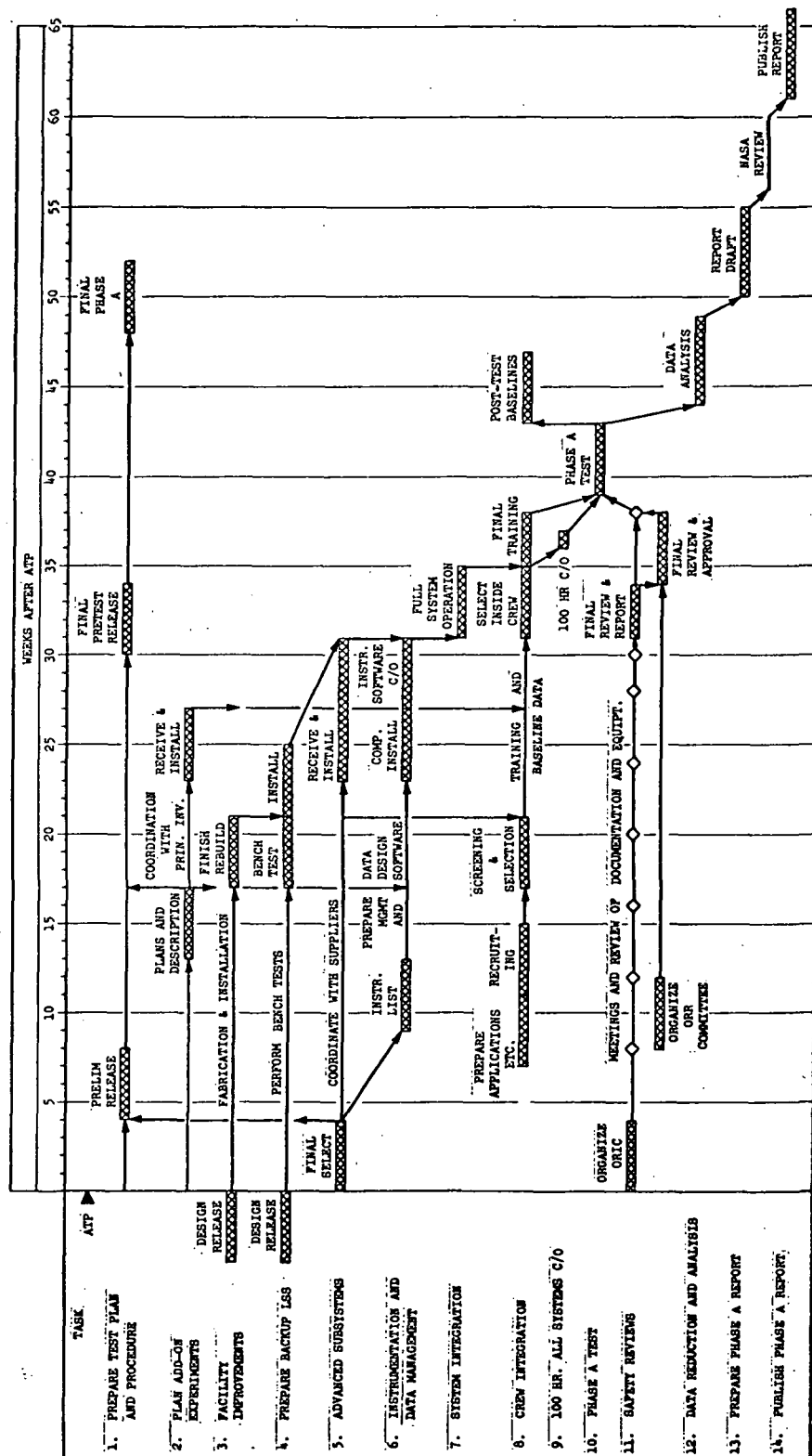


FIGURE 1. PHASE A EXTENDED MANNED TEST FUNCTIONAL SEQUENCE OF EVENTS

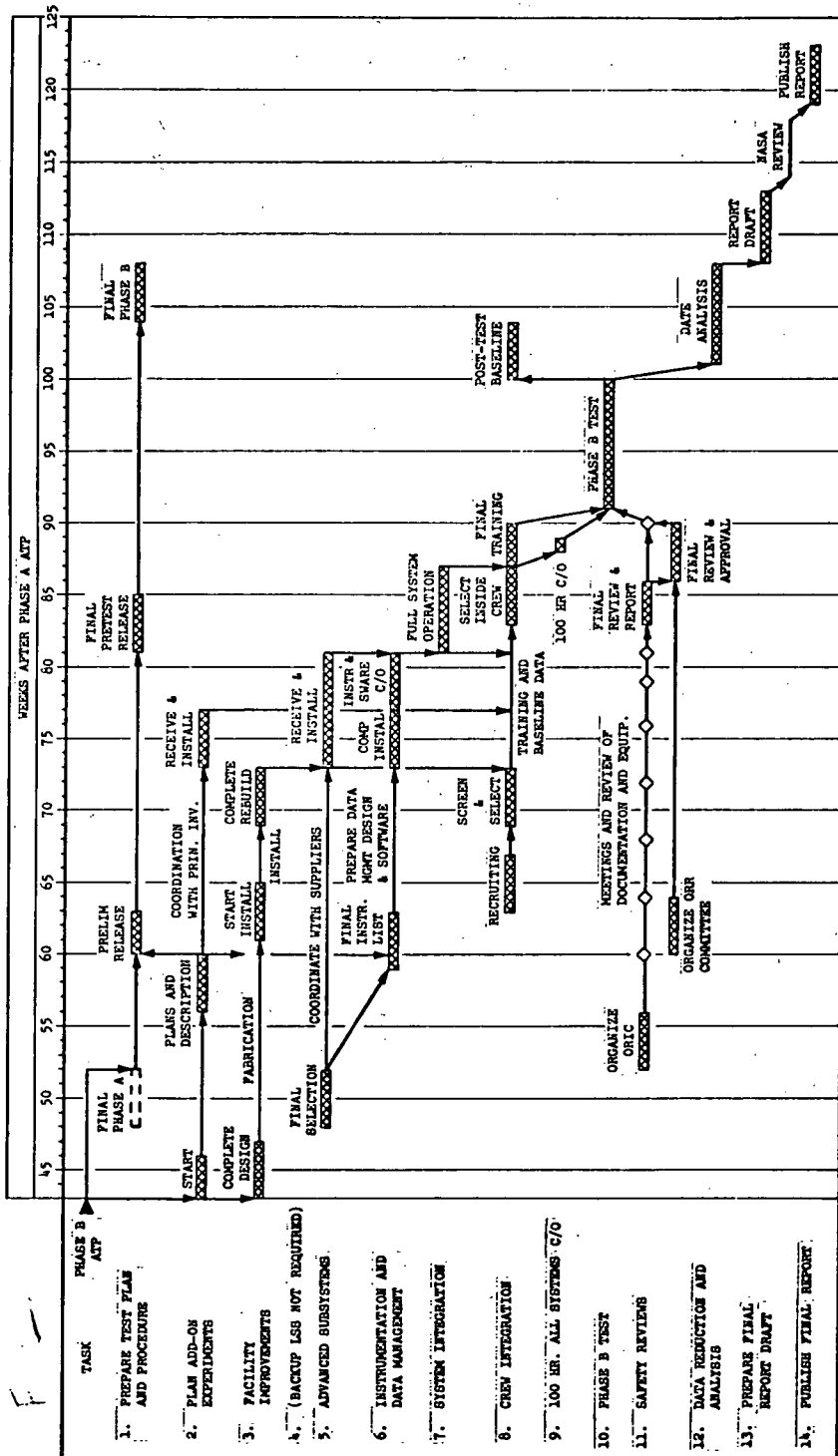


FIGURE 2. PHASE B EXTENDED MANNED TEST FUNCTIONAL SEQUENCE OF EVENTS

This study effort considered the entire spectrum, with major emphasis on the definition of crew activity scheduling. Table 2 presents the elements of a time-phased program for crew activity scheduling, showing a progression from a minimum program in Phase A (4-week test) to an expanded, fully operational capability in Phase B (9-week test). The following paragraphs present the rationale for the material presented in Section 8.3 of the Test Plan.

TABLE 2

CREW ACTIVITY SCHEDULING FORMAT

PHASE A	PHASE B
Computerized Crew Activity Schedule	Computerized Crew and Operating Staff Activity Schedules
Minor daily reschedule by Crew Commander; major reschedule effort by outside staff with computer assistance	Minor and daily reschedule by Crew Commander with direct access for computer assist.
Hardcopy format -for use of crew and operating staff	Hardcoy format for use of crew and operating staff; computer generated video display; and hardcopy printout of activity schedule
Use GPM and ODM for generation of Mission Profile and Activity Schedule.	Use all capabilities of SSMM for planning, generation of activity schedules, simulating contingencies and updating schedules.

### 3.2.3.1 Ground Rules

To provide a basis for crew activity scheduling, ground rules had to be established for work/rest cycles, crew time allocations, fixed time events, and use of free time.



Trade study analysis of two different work/rest cycles - 2 crewmen up/2 crewmen down vs 4 crewmen up/4 crewmen down - was conducted. Evaluation criteria consisted were safety, availability of skills, response times to emergencies or other unanticipated events, space requirements, and operational considerations. The 2 up/2 down work/rest cycle was selected on the basis of crew safety and operational considerations. Continuous monitoring of the prototype hardware insures maximum opportunity to detect minor variations in equipment operation and immediate availability of personnel to make adjustments to preclude major malfunctions from occurring. It also provides an added factor of crew safety by assuring the availability of a crew member in the event of an emergency situation. The selected work/rest cycle also permits "hot bunking" with consequent reduction in volume required for sleep stations.

Allocations of blocks of crew time to sleep, meals, free time, and duty were arrived at by review and analysis of 90-day test results. These results indicated that time allocated to sleep should be increased from 8.0 to 8.5 hours and that the time for meals could realistically be decreased from 3.5 hours to 2.5 hours.

Fixed-time events are those crew activities which are scheduled for specific times of the day in advance as part of the baseline. They thus become scheduling constraints around which other activities must be scheduled. Sleep and meal periods were selected as fixed-time events and scheduled on the basis of having all four crewmen up and available to the maximum extent possible during the normal plant work schedule (8:00 a.m.-4.42 p.m.), and to assure a maximum capability for response to support staff engineering requests.

The allocation of 3.0 hours per day of free time per crewman was based on results of the 90-day test. Free time is defined as time for recreation and includes unscheduled exercise, snacks, personal phone calls, and resting as well as strictly recreational pursuits. The specific use of this time should be at the discretion of the crewmen and, therefore, discrete free time events will not be scheduled. This policy provides opportunity for research investigation into the free choices selected by the crewmen.

### 3.2.3.2 Procedures

The NASA Space Station Mathematical Model was selected for computerized generation of Crew Activity Schedules, based on the results and recommendations from the 90-day test. General Planning Model (GPM) and One-Day Model (ODM) will satisfy the minimum requirement to meet the program objectives of the Phase A Test.

The selection of a "hardcopy" Crew Activity Schedule format for presentation of daily schedules to the crew was based upon crew recommendations from the 90-Day Test and the phased plan for development of an increased crew autonomous rescheduling capability. Minor daily changes made by the Crew Commander can be annotated on the schedule; major changes made by the operating staff can also be annotated on the schedule by the Crew Commander. Crew members from the 90-Day Test all recommended that a "hardcopy" schedule be provided in future tests regardless of other methods of schedule presentation which may be made available. The specific format to be used has several advantages from a crew standpoint. It presents a time-oriented picture showing the duties of all crewmen, provides a means for permanently annotating changes, and lastly, provides a psychological effect when crewmen file the completed daily schedule sheets.

Since crew activity scheduling starts with identification of required crew activities, an initial effort was undertaken to compile a list of crew events and their frequencies. Discussions were held with the various engineering, medical, and crew integration personnel concerned with test planning and a tentative list of crew events was generated. Table 3 contains the results of these preliminary investigations and provides a basis for an expanded Crew Event Matrix.

The effort associated with Crew Activity Scheduling will be a combination of gathering and formulating of basic data for the Crew Event Matrix, converting the data to computer input, and exercising the GPM and ODM. Work will be initiated early in the program to insure planning support and problem identification to program management. Support staff personnel will be available

TABLE 3.

TENTATIVE LIST OF CREW EVENTS

1. MEDICAL

- a. Daily, basal body weight, oral temperature, and skin folds
- b. Daily, medical interview
- c. Weekly, pulmonary spirometry
- d. Weekly, hematology
- e. Daily, urine aliquots
- f. Weekly serum samples
- g. Bi-weekly nasopharyngeal microflora samples
- h. Potable water samples (TBD schedule), biological tests
- i. Atmosphere samples (TBD schedule), biological tests
- j. Surface samples (TBD schedule), biological tests
- k. Daily physical conditioning
- l. On request: occult blood, urine, feces, urinalysis, ECG, blood pressure

2. MAN-SYSTEMS

- a. Weekly, behavioral interview
- b. Once, onboard cohesion session
- c. Daily, onboard diary
- d. Daily, scheduled recreation
- e. 1/10 days, habitability questionnaire
- f. 3/day/cm., psychomotor tests

3. CREW PERSONAL EVENTS

- a. Daily, meals
- b. Daily, sleep
- c. Daily, waste management
- d. Daily, body hygiene/shower
- e. Weekly, bed linen change
- f. Bi-weekly, cabin cleaning
- g. Free Time: unscheduled exercise, TV/radio/slides, napping, phone calls, reading, resting, snacks, etc.

4. OPERATIONAL

- a. Daily, activity schedule review and rescheduling
- b. Once, equipment start-up
- c. Daily, mass balance data collection
- d. Daily, safety inspection
- e. TBD, collect atmosphere samples
- f. TBD, collect surface samples
- g. TBD, collect water samples
- h. TBD, equipment monitoring
- i. TBD, scheduled maintenance of equipment
- j. Once, equipment shut-down

during the test to assist in major rescheduling activities. Nominal operating staff monitoring will be provided by the Communications Monitor and the Test Conductor.

### 3.3 LIFE SUPPORT SYSTEM DEFINITION

#### 3.3.1 Selection of Advanced Subsystems

Advanced life support subsystems, which are considered to be potential candidates for testing in either Run A or B, have been quantitatively evaluated. The current status of each subsystem and their expected availability dates have been determined. Subsystem characteristics, including process flows, performance and physical characteristics, were included. Additionally, subsystem interface and support requirements including power, cooling and heating, and fluid transfer also were included. A summary of respective subsystem evaluations is presented in the following paragraphs. Subsystems which have been tested in previous manned simulator runs are not discussed in this section.

##### 3.3.1.1 Water Reclamation

#### 1. RITE Waste Management-Water System (WM-WS):

Cognizant Agency: This program is jointly administered by NASA, U.S. Air Force and Atomic Energy Commission. The system contractor is the General Electric Company.

#### Current Status:

1. System fabrication is scheduled for completion by 31 December 1971.
2. A two-months system testing and refurbishing, including a 10-day system test at General Electric, is scheduled for completion by 1 March 1972.

#### Subsystem Characteristics:

1. The system processes the following amounts of solid and liquid wastes, in pounds per day: 1.2 feces, 14.0 urine, 20.0 respiration and perspiration, 24.0 wash water and 1.2 trash.

2. The system recovery rates are 30.0 lbs/day of potable water and 24.0 lbs/day of wash water.
3. The system will have the capability of operation with two radio-isotope heat sources (RITE), one with an output of 400 thermal watts for the vapor pyrolysis and incinerator units and the second, operating at a lower temperature, with an output of 900 watts for the evaporator.
4. Shielding will limit the radiation dose rate to less than 0.6 MREM/hour at 3 feet from the system.

Availability:

The RITE WM-WS is expected to be available for the extended manned tests in March 1972, if no additional schedule slippages occur.

Interfaces and Support Requirements:

1. Coolant, 1 GPM at 35 to 50°F inlet temperature.
2. Vacuum source,  $10^{-6}$  mm Hg, capacity to be determined.
3. Oxygen supply, quantity to be determined.
4. Nitrogen supply, quantity to be determined.
5. Electrical power, types and quantities to be determined.

2. Reverse Osmosis

Cognizant Agency: NASA/MSC

Current Status:

1. The reverse osmosis subsystem will be used for wash water recovery in the integrated water and waste management system being developed for the Space Station Prototype (SSP), by Chemtrac, Inc. Hamilton-Standard Division of United Aircraft Corporation is the prime contractor for the SSP.

2. The reverse osmosis cells are of the Permasep type manufactured by DuPont. Most of the SSP development testing utilized Permasep B-5 cells. The more efficient Permasep B-9 cells will replace the B-5 cells in future tests.
3. Testing of the B-9 type cells is planned to start soon at Chemtrac, Inc.

#### Subsystem Characteristics:

1. Subsystem characteristics will be influenced by the wash water standards adopted for the test. The SSP program requires that wash water be potable, in which case charcoal columns are used downstream of the reverse osmosis cells.
2. The SSP reverse osmosis subsystem required two B-5 cells in series to meet potability standards. One B-9 cell is expected to suffice.
3. The Permasep B-5 has the following operating conditions: 600 psi, 72°F, 95% water recovery, feed contains 1800 PPM solubles, permeate has 400 PPM solubles.

#### Subsystem Availability:

Tests may be conducted with a unit utilizing DuPont's Permasep B-9 cells after the completion and analysis of SSP test data. The SSP testing of reverse osmosis cells type B-9 is scheduled to be completed in November, 1971.

#### Interfaces and Support Requirements:

The following requirements, based on SSP reverse osmosis subsystem performance, are estimated for a wash water processing rate of 380 lbs/day, which includes shower, wash, and clothes and utensil wash water.

1. Reverse osmosis high pressure pump power = 198 watts (AC), average, and 230 watts peak.
2. Reverse osmosis controller power = 10 watts (DC), average, and 30 watts peak.
3. Charcoal required = 1.36 lbs/day
4. Germicide selected for use with reverse osmosis is Vancide BN
5. Surfactant selected for use with reverse osmosis is Miranol C2M.

### 3. Combined Reverse Osmosis/Multifiltration

Cognizant Agency: NASA/MSC (reverse osmosis), NASA/LaRC, MSC and MSFC (multifiltration).

#### Subsystem Status:

1. A multifiltration subsystem has been operated successfully in NASA/MDAC 90-Day Test.
2. Reverse osmosis subsystem status: See above.

#### Subsystem Characteristics:

1. The subsystem will include particulate filters, for food particles removal, upstream of the reverse osmosis cells.
2. Brine from reverse osmosis cells will be routed into the multifiltration unit for final processing.
3. The hybrid system is expected to increase the life of both reverse osmosis and multifiltration units.
4. Definitive subsystem characteristics will be obtained after further analysis and bench testing.

#### Availability:

Subsystem availability is predicated primarily on the availability of the reverse osmosis unit as discussed above. The combined reverse osmosis/multifiltration subsystem should be integrated and bench-tested prior to the manned test. Sufficient time also must be made available to incorporate any necessary subsystem modifications, based on the results of the bench test.

#### Interfaces and Support Requirements:

The combined reverse osmosis/multifiltration subsystem will have the following requirements, in addition to those listed for the reverse osmosis unit, above:

1. Circulation pump electrical power = 20 watts
2. Expendable filters: To be determined from bench testing.

#### 4. Vapor Compression

Cognizant Agency: NASA/MSC

#### Current Status:

1. The vapor compression subsystem will be used for the recovery of urine, flush water, condensate and wash water brine for the SSP. The subsystem is being developed by Chemtrac, Inc., under contract to the SSP prime contractor, Hamilton-Standard Division of United Aircraft Corporation.
2. A vapor compression pre-prototype unit was built and tested for 180 days. Data obtained from this testing are being used in developing the flight type subsystem for the SSP.

#### Subsystem Characteristics:

1. The six-man SSP vapor compression subsystem has the following input rates, in pounds per day: urine and flush 32.64, humidity, sabatier water and non-metabolic condensate = 39.66, commode flush 19.8, wash water brine 39.3 (total 131.4). This processing rate is achieved by two units operating in parallel.



2. The following are the subsystem output rates, in pounds per day:  
potable water 39.2, flush water 31.8, wash water distillate 60.4  
(total 131.4)

Availability:

1. The pre-prototype unit may be revamped, in approximately 4 to 6 months, and used in manned tests to provide actual data for the SSP.
2. The flight type unit is scheduled to be completed in March 1974.

Interface and Support Requirements:

1. The power requirements for the vapor compression unit and associated equipment are as follows:
  - a. Two vapor compression stills and purge and recycle pumps = 320 watts
  - b. Pre-treatment, controls and autoclave = 360 watts
  - c. Water dispensing accumulator heat exchanger = 245 watts
  - d. Water storage (heater, pump and controls) = 1654 watts
2. Solids disposal = 1.4 lbs/day as 50 per cent H<sub>2</sub>O slurry.
3. Make-up water = 0 lbs/day
4. Additional interface and support requirements: to be determined

5. Vapor Diffusion Reclamation (VDR):

Cognizant Agency: NASA/LaRC

1. Breadboard type system developed by Hamilton-Standard Division of United Aircraft Corporation for LaRC, to show system feasibility.
2. The system was bench tested, including a continuous 90-Day Run at Hamilton Standard.
3. The system was packaged under a different contract and delivered to LaRC in July 1971.

#### Subsystem Characteristics:

1. Membrane used in the VDR is polyvinyl-chloride (PVC).
2. Urine is chemically treated prior to processing in the VDR.
3. The evaporator modules are replaceable after membrane deterioration.
4. Residue slurry has 50% solids concentration (by weight).
5. More definitive subsystem characteristics should be developed after additional subsystem evaluation.

#### Availability:

The VDR system developed by Hamilton-Standard is currently available at NASA/LaRC.

#### Interfaces and Support Requirements:

Subsystem interfaces and support requirements are to be determined after additional subsystem analysis.

#### 6. Flash Evaporation/Pyrolysis:

Cognizant Agency: NASA/MSC

#### Current Status:

1. The system is under development by AiResearch Manufacturing Company for NASA/MSC.
2. A bread-board system was developed with a 5-day test completed.
3. A new contract has been initiated which includes a 120-day test to primarily evaluate the phase separator.

#### Subsystem Characteristics:

1. Unit capacity = 1.0 to 1.25 lb/hr.
2. Unit size = 1 ft. x 1.5 ft. x 3 ft. (exclusive of tank).
3. Unit weight: Processor = 69 lbs, urine collection & transfer = 38 lbs., water collection and transfer = 29 lbs., instrumentation = 12 lbs.

#### Availability:

Subsystem availability is expected in 18 to 24 months.

#### Interfaces and Support Requirements:

1. Subsystem power requirements = 195 watts (100 watts for compressor, balance for reactor, phase separator and controls).
2. More definitive support requirements to be determined after additional subsystem analysis.

#### 7. Electrovap (closed air evaporation system with electrolytic pre-treatment):

Cognizant Agency: NASA/MSFC and LaRC

#### Current Status:

1. Air evaporation systems (open) developed and tested in NASA/MDAC 60-day and 90-day tests.
2. Electrolytic pretreatment subsystem prototype has been developed for NASA/LaRC. Program completed June 1971.
3. Electrovap, a radioisotope-heated closed air evaporation system with electrolytic pretreatment has been initiated by NASA/MSFC and LaRC.

#### Subsystem Characteristics:

1. Six-man system capacity.
2. Subsystem fixed weight = 85 lbs.
3. Subsystem launch spares and expendables = 95 lbs.
4. Heat load = 2400 Btu/hr
5. Subsystem power requirement = 520 watts, average (360 watts for electrolysis, 60 watts for controls and 100 watts for blower).
6. Definition of additional subsystem characteristics is in progress.

Availability:

1. A hybrid system comprised of MDAC air evaporation system in a closed mode and NASA/LaRC electrolytic pre-treatment subsystem may be assembled in approximately six months.
2. The flight-type electrovap system availability is contingent on contract initiation.

Interfaces and Support Requirements:

Subsystem interfaces and support requirements are to be determined after additional subsystem analysis and testing.

3.3.1.2 Carbon Dioxide Collection

1. H<sub>2</sub>-Depolarized Cells:

Cognizant Agency: NASA/ARC

Current Status:

1. Currently a one-man unit (15-cell module) is undergoing parametric and life testing at Life Systems, Inc., for NASA/ARC.
2. Additionally, the above contract includes a study of interface problems between the Sabatier reactor and the hydrogen-depolarizer in order to operate the system without an accumulator.
3. The development of a 6-man system, sized for use in the SSP, also has been initiated by NASA/ARC, with Life Systems, Inc., as the contractor.

Subsystem Characteristics:

1. The subsystem maintains CO<sub>2</sub>-level < 1.0 mmHg.
2. Present unit is aircooled.
3. The CO<sub>2</sub>-collection process is electrochemical, with Cs<sub>2</sub> CO<sub>3</sub> as electrolyte.
4. The subsystem consumes H<sub>2</sub>, produces some electricity and water.

5. Additional subsystem characteristics should be defined after further subsystem analysis.

Availability:

1. The subsystem will be available in August, 1972, with parametric but no life tests.
2. February 1973 is the scheduled subsystem delivery date with life tests completed.

Interfaces and Support Requirements:

1. The six-man unit will require approximately 300 watts AC plus 20 watts DC (This is in addition to the power generated by the unit itself). The unit blower would require 100 watts, AC, with the additional 200 watts AC and 20 watts DC for controls and instrumentation.
2. The current unit is air-cooled, using forced circulation. It rejects 30 Btu/Hr/man. Its minimum operating temperature is 100°F.
3. Flow characteristics -

CO <sub>2</sub> transfer rate	0.11 lb/hr/man
H <sub>2</sub> input	1.7 Standard Liter/min/man
H <sub>2</sub> side pressure drop	6" H <sub>2</sub> O
Oxygen consumption =	1.2 lb/man/day

2. Regenerable Solid Desiccants:

Cognizant Agency: NASA/MSC

Current Status:

1. The system is under development for space shuttle application.
2. Initial work on a similar system was performed under NASA/LaRC contract NAS1-9356.

3. System is currently in laboratory development test phase.
4. Prototype system fabrication will be completed in December 1972.
5. Life testing of prototype extends through 1973.
6. Data from other solid amines CO<sub>2</sub>-collectors are applicable to the development of this subsystem.

Subsystem Characteristics:

1. System will be used to control both CO<sub>2</sub> and humidity in Shuttle.
2. The system will be sized to maintain CO<sub>2</sub> level less than 7.6 mmHg.
3. System is not compatible with oxygen recovery system operations.
4. More definitive subsystem characteristics should await further development.

Availability:

The subsystem as currently planned will not be available until January 1973 (with no life testing) or December 1973 (with life testing).

Interfaces and Support Requirements:

Subsystem interfaces and support requirement are yet to be defined.

3.3.1.3 OXYGEN RECOVERY:

1. Bosch:

Cognizant Agency: NASA/MSFC

Current Status:

1. A 4-man unit with expendable catalyst cartridges was developed by General Dynamics Convair for NASA/LaRC. The program was completed in November, 1970. The unit has two reaction chambers, with one of them continuously on-line while the other is allowed to cool and the spent cartridge replaced. Steel wool was selected as the catalyst.

2. Subsequently, General Dynamics Convair built another unit, with only one reactor and with a 9-man capacity under company funds.
3. NASA/MSFC has awarded General Dynamics Convair a contract to build a new unit, under a 16-month contract which started May 1, 1971. The unit is being designed with an isotope heater. General Dynamics indicate that the new unit will use considerably less power than the 4-man Langley. (Power is required for compressor, warm-up and instrumentation.) Attempts will be made to modify the catalyst cartridge such that only the liner is replaceable, to save on the weight of expendables.

#### Subsystem Characteristics:

1. Catalyst replacement interval = 3 days.
2. CO<sub>2</sub> processing rate = 13.92 lbs/day
3. Recycle gas rate = 9 lbs/hr
4. Recycle gas composition, % by volume: 40 (H<sub>2</sub>), 30 (CH<sub>4</sub>), 20 (CO), and 10 (CO<sub>2</sub>).
5. Six-man system will utilize isotope heater.

#### Availability:

The NASA/MSFC unit is expected to be delivered in December, 1972. The NASA/LaRC unit is currently available at Langley.

#### Interfaces and Support Requirements:

1. Coolant (water) inlet temperature = 40°F
2. Coolant flow = 60 lb/hr
3. Compressor power = 450 watts
4. Heater and control = 500 watts (110 vac, 60 ~).

## 2. Sabatier/Resistojet:

Cognizant Agency: NASA/LaRC

### Current Status:

1. Sabatier  $O_2$  - recovery system has been operated during 60- and 90-day tests.
2. A resistojet propulsion system propellant management and control subsystem is under development for NASA/LaRC.
3. Six-man Sabatier system is under development as part of SSP program.

### Subsystem Characteristics:

1. MDAC Sabatier system capacity = 9.0 lbs  $CO_2$ /day.
2. Resistojet propellant control system will be developed compatible with modular space station 6-man life support system.

### Availability:

1. Resistojet propellant control system will be available October 1972.
2. MDAC Sabatier system is presently available for integration with resistojet propellant control system.

### Interfaces and Support Requirements:

1.  $CO_2$  storage pressure = 300 psia
2.  $CH_4$  storage pressure = 300 psia
3.  $H_2O$  storage pressure = 50 psia
4. Additional interfaces and support requirements: to be defined after further subsystem analyses.



### 3. Flight-Type Sabatier:

Cognizant Agency: NASA/MSC

#### Current Status:

The flight type Sabatier subsystem is being developed by Hamilton-Standard Division of United Aircraft Corporation, for CO<sub>2</sub> reduction in the SSP.

#### Subsystem Characteristics:

1. Reactor operating pressure = 15 psia
2. Reactor is air cooled
3. Exhaust gases include CH<sub>4</sub>, H<sub>2</sub>O, excess CO<sub>2</sub> and unreacted H<sub>2</sub>.
4. Reactor operating temperature = 500 ± 25°F

#### Availability:

An engineering development prototype is expected to be made available for use in an extended manned simulator test by July, 1972.

#### Interfaces and Support Requirements:

1. CO<sub>2</sub> accumulator pressure = 50 psia
2. Liquid coolant temperature = 50°F
3. Gas coolant temperature = 65 to 75°F
4. Gas coolant flow rate = 33 to 100 lbs/hr

### 4. Solid Electrolyte:

Cognizant Agency: NASA/ARC and LaRC

#### Current Status:

1. Research work has been sponsored by NASA/ARC since 1965. A one-man (127-amps, three module) solid electrolyte reactor and

a CO disproportionation reactor were developed by Applied Electrochemistry, Inc.

2. A 1/4 man closed-loop solid electrolyte oxygen regeneration system has been developed by Westinghouse Electric Corporation under NASA Langley sponsorship, and undergone a successful 180-day life test.

#### Subsystem Characteristics:

1. Solid electrolyte reactor temperature = 1550°F
2. CO-disproportionation reactor temp. = 970°F
3. Disc electrolyte made of Scandia-stabilized zirconia (Applied Electrochemistry), or a platinum-zirconium oxide cermet (Westinghouse).
4. Cell voltage = 1.88 to 2.04 VDC
5. O<sub>2</sub> purity = 96%

#### Availability:

1. Only breadboard type modules are available.
2. System may be available for Phase B test if program development is accelerated.

#### Interfaces and Support Requirements:

1. Electrolysis power = 239 to 259 watts/man
2. Further interfaces and support requirement to be defined after additional subsystem analysis.

#### 3.3.1.4 Water Electrolysis:

1. Solid Polymer Electrolyte (SPE):

Cognizant Agency: NASA/LaRC and MSC.

#### Current Status:

1. Two test units have been built for LaRC: a 7-cell stack, tested one year; and a one-man module, tested 1500 hrs.

2. Design of SSP system is due November, 1971, followed by selection of either solid polymer or KOH electrolyte system for development for SSP.
3. The follow-on phase of NASA/LaRC contract to develop a 4-man system has been initiated.

#### Subsystem Characteristics:

1. Nominal cell voltage = 1.5 VDC
2. Nominal cell operating temp. = 160°F
3. Electrolyte is ion exchange plastic sheet developed by DuPont and treated further by G.E.
4. System is operated at high current densities up to 1000 ASF and discharge gas pressure of up to 700 psig.
5. System's normal operation is at 200 ASF.

#### Availability:

1. Availability of the 4-man system under development for NASA/LaRC is expected in July, 1972.
2. If the SPE system is selected for the SSP, the system may be available in March, 1973.

#### Interfaces and Support Requirements:

1. Electrolysis module voltage = 40 to 60 VDC.
2. Instrumentation voltage = 25 to 31 VDC
3. Power input = 386 to 463 watts/man
4. Electrolysis current = 10 to 12 amps/man
5. Instrumentation power = 20 watts.
6. Coolant temperature = 50°F.
7. Maximum cooling = 217 Btu/hr/man.

## 2. Circulating KOH Electrolyte:

Cognizant Agency: NASA/LaRC

### Current Status:

1. A 4-man subsystem has been developed by Lockheed Corporation and operated during the NASA/MDAC 90-Day Test for 70 Days.
2. The Lockheed subsystem is undergoing an evaluation test at MDAC.

### Subsystem Characteristics:

1. Nominal cell voltage = 1.8 to 2.1 VDC
2. Nominal operating temperature = 75°F
3. Electrolyte = 30% KOH solution
4. Operating current density = 100 ASF

### Availability:

1. The system under test at MDAC requires additional development and repackaging if used in manned test.
2. NASA/MDAC comparative evaluation test will be completed July, 1972, with the most successful unit from the test to be recommended for further development.

### Interfaces and Support Requirements:

1. Coolant (water) required = 0.5 GPM at 55°F.
2. Oxygen discharge pressure = 21 to 27 PSIG.
3. Hydrogen discharge pressure = 9 PSIG.
4. The subsystem has the following power requirements:

30 ma	120/208 VAC, 400 Hz (3 sec. on, 15 min. off)
2.5 amp	115 vac, 1 phase, 60 Hz for controls and the oxygen compressor
1300 watts	DC on high mode operation, continuous
445 watts	DC on low mode operation, 2 hours/day

### 3. LSI Static Feed Electrolyte

Cognizant Agency: NASA/ARC

#### Current Status:

Electrolysis modules only have been developed as part of aircrew oxygen system development sponsored by NASA/ARC.

#### Subsystem Characteristics:

1. Nominal cell voltage = 1.55 at 100 ASF.
2. Nominal operating temperature = 160 to 180°F
3. Electrolyte is 25% KOH solution
4. Module was shown to operate at 200 and 350 ASF.
5. System requires pretreated feed water (out-gassed and ion-filtered).

#### Availability:

The development of a system based on LSI hardware is estimated to require a one-year program. None is currently announced.

#### Interfaces and Support Requirements:

1. Subsystem requires 28 VDC.
2. Instrumentation power = 20 watts
3. Modules are air-cooled through fins.

### 4. Teledyne-Isotopes Static Feed Electrolysis:

Cognizant Agency: NASA/MSD and LaRC.

#### Current Status:

1. A prototype system developed by Allis-Chalmers has been upgraded by MDAC (4 to 6-man capacity) and is undergoing evaluation testing.

2. A second Allis-Chalmers system is available at NASA/LaRC.
3. Teledyne-Isotopes would only supply cells but is not involved in system development.

#### Subsystem Characteristics:

1. Nominal cell voltage = 1.55 at 100 ASF.
2. Nominal operating temperature = 160 to 180°F.
3. Electrolyte is 35% KOH solution (max).
4. Maximum operating capacity = 150 ASF.
5. System operates with no pretreatment of water.

#### Availability:

1. The system under test at MDAC requires additional development and packaging.
2. The system available at NASA/LaRC requires additional refurbishing if used in manned test.

#### Interfaces and Support Requirements:

1. Subsystem requires 28 VDC.
2. Instrumentation power = 20 watts
3. One GPM cooling water at 50°F

#### 3.3.1.5 Personal Hygiene

1. Zero-G Whole Body Shower:

Cognizant Agency: NASA/LaRC

#### Current Status:

1. Subsystem development program has been initiated by NASA/LaRC.

#### Subsystem Characteristics:

1. The enclosure is 80 inches tall, 32 inches in diameter, and tapered to 20 inches at bottom (inside dim).
2. A two-phase separator on air stream is located externally.
3. The shower includes a hand-held sprayer, soap dispenser and vacuum cleaner.
4. Some of the recycle air flow must be diverted for CO<sub>2</sub> removal.

#### Availability:

The NASA/LaRC zero whole body shower is expected to be delivered in December 1972.

#### Interfaces and Support Requirements:

1. Recycle air flow = 200 CFM.
2. Air pre-heat temperature = 95°F.
3. Vacuum cleaner capacity = 10 CFM
4. Water flow = less than 8 lbs per shower.

#### 3.3.1.6 Waste Management

##### 1. Skylab A Urine Separator

Cognizant Agency: NASA/MSFC

#### Current Status:

1. This unit is being developed to be used in Skylab A.
2. A plastic working model is available and a metallic engineering development unit is currently in fabrication.

#### Subsystem Characteristics:

1. Gas flow rate = 2 CFM
2. Gas pressure drop in unit = 6 inches of water at 2 CFM
3. Liquid flow rate = 45 ml/sec.
4. Liquid quantity per usage = 800 ml, maximum

#### Availability:

An engineering development model is expected to be available for a manned simulator test by February, 1972.

#### Interfaces and Support Requirements:

1. Operating voltage = 24 to 30 VDC
2. Electrical power consumption = 30 watts, maximum
3. Separated liquid delivery back pressure = 2 to 3 inches of water above ambient.

#### 2. Shuttle Waste Collection Unit

Cognizant Agency: NASA/MSC

#### Current Status:

1. This unit is being developed for possible use in the Shuttle.
2. The unit is currently in the design stage, with an engineering development operating model expected to be available in approximately 6 months.
3. The unit is being developed by Hamilton-Standard Division of United Aircraft Corporation.

#### System Characteristics

1. The Shuttle Waste Collection Unit is designed to accommodate both males and females.



2. An air flow urinal, utilizing water flush, is used.
3. Fecal collection is aided by air flow into the unit where feces are shredded by a motor driven slinger and then vacuum dried.
4. Filters are used for odor and bacterial control.
5. More definitive subsystem characteristics are to yet be defined.

Availability:

An engineering development operating model is expected to be available in April, 1972.

3.3.1.7 Life Support Subsystem Recommendations

The rationale used in selecting life support subsystems for Runs A and B was based on developing new technology for integrated advance life support systems applicable to earth orbital programs. However, subsystem availability, especially in case of Phase A run, was a prominent factor in the selection process.

The life support subsystems recommended for Phase A run are given in Table 4. A number of the subsystems shown in Table 4, namely: 1) The  $H_2$ -Depolarized  $CO_2$  Concentrator, 2) the Flight-Type Sabatier Reactor, 3) the Solid Polymer Electrolyte Electrolysis Unit, 4) the Combined Reverse Osmosis/Multifiltration Subsystem and 5) the Zero-Gravity Shower, are in the design and/or fabrication phase of development. The delivery of these subsystems on schedule would allow only about three months for bench testing, installation, integration with other subsystems and unmanned system testing.

In the area of potable water recovery, the testing of both an advanced subsystem (RITE or vapor compression) and closed air evaporation units is recommended. Each of the two units will process half of the urine, urine flush water and reverse osmosis brine. The recommended arrangement will result in providing engineering test data necessary for the development of the electrovap system (combined electrolytic pretreatment and closed air

Table 4

## RECOMMENDED LIFE SUPPORT SUBSYSTEMS FOR PHASE A RUN

Subsystem/Function	Primary Subsystems	Baseline Subsystems
CO <sub>2</sub> Removal and Concentration	o H <sub>2</sub> -Depolarized CO <sub>2</sub> Concentrator	o Molecular Sieves
Contaminant Control	o Catalytic Burner/Sorbent Beds/ Filters	o Same
CO <sub>2</sub> Reduction	o Flight-Type Sabatier	o Same
Oxygen Generation	o Solid Polymer Electrolyte	o KOH Wick Electrolysis
Atmosphere Monitoring and Control	o Flight-Type Two-Gas Controller with Mass Spectrometer	o Built-in Redundancy
Urine Pretreatment	o Electrolytic	o Chemical
Potable Water Recovery	o Vapor Compression	o Closed Air Evaporation
Wash Water Recovery	o RITE WM/WS	o Multifiltration
	o Combined Reverse Osmosis/Multifiltration	o Multifiltration
Waste Management	o Shuttle Waste Collection Unit	o Dry John
	o Skylab A Urine Separator	o Same
	o RITE WM/WS	o Same
Food Management	o Freeze-Dried Food/Microwave Oven	o Same
Clothes Washer	o Commercial Unit	o Same
Personal Hygiene	o Zero-Gravity Shower	o Sponge Bath
Trash Disposal	o Dry Trash Compactor	o Same

evaporation), and also for the integration of electrolytic pretreatment unit with the advanced water recovery subsystem.

Additional engineering test data also will be provided from testing the combined reverse osmosis/multifiltration subsystem, discussed in Section 3.3.1.1, above.

For waste management, two units considered for specific spacecraft applications have been recommended. These are the Shuttle Waste Collection unit and the Skylab A Urine Separator. Both units are in the development stage. The testing of the engineering development operating modules would provide valuable test data useful to the Shuttle and Skylab program efforts.

Phase A run would also provide the opportunity to obtain practical test data on the zero-gravity whole body shower which is considered for future long duration space missions.

The life support subsystems recommended for Phase B run are given in Table 5. Two complete advance life support systems are recommended for testing, in sequence, in phase B run. Each system would be tested for half the run's duration and would also be used as back-up during the other system's operation. In some areas, two alternate subsystems are shown for the same function. For example, both the flight type vapor compression and the RITE WM-WS are considered for potable water recovery. In such instances, the final choice of subsystem selection may be made when their availability is more firmly decided. It should also be mentioned that some of the subsystems shown in Table 5, notably the solid electrolyte and the wet oxidation, require accelerated development efforts to produce working prototype before the end of 1973.

### 3.3.2 Baseline Subsystems Description

The baseline life support subsystems described in this Section are representative of those that will be required to provide the backup functions for the Phase A advanced life support subsystems only. Since the Phase B test will evaluate two complete advanced life support systems, the baseline subsystems will not be required.

Table 5

## RECOMMENDED LIFE SUPPORT SUBSYSTEMS FOR PHASE B RUN

Subsystem/Function	First Advance System		2nd Alternate System
CO <sub>2</sub> Removal and Concentration	o	Improved H <sub>2</sub> -Depolarized CO <sub>2</sub> Concentrator	o Improved Amines
Contaminant Control	o	Isotope Heated Catalytic Burner/Sorbent Beds/Filters	o Catalytic Burner/Sorbent Beds/Filters
CO <sub>2</sub> Reduction	o	Bosch	o Sabatier/ResistoJet
	o	Solid Electrolyte	
Oxygen Generation	o	Solid Electrolyte	o Advance Circulating KOH Electrolyte
Potable Water Recovery	o	Flight-Type Vapor Compression	o ElectrovaP (closed air evaporation/electrolytic pre-treatment)
	o	RITE WM-WS	
Wash Water Recovery	o	Reverse Osmosis	o Combined Reverse Osmosis/Multifiltration
Waste Management	o	RITE WM-WS	o Advanced Integrated Waste Management System
			o Wet Oxidation

The proposed baseline subsystems were derived from the baseline life support equipment utilized during the recently completed 90-day test. Although these subsystems consist of units with a previous history of development evaluation in extended manned test, extensive redesign will be necessary to provide the required interface with the proposed advanced subsystems. In addition, data from the 90-day test could be utilized to upgrade the baseline units to provide improved equipment performance and reliability.

The baseline subsystem redesign effort will be discussed in this Section. Detail descriptions of these units are contained in Section 5.0 of the Preliminary Test Plan NASA CR-111999 prepared during this study.

#### 3.3.2.1 Water Management Subsystem

Water recovery will be performed by separate units for potable and wash water. The potable water recovery unit includes: (1) the closed-cycle wick evaporator, (2) the potable water multifilter, (3) potable water storage and distribution, and (4) the backup water supply. The wash water unit includes: (1) the zero-g heated water tanks, (2) the multifiltration module, (3) the heat exchanger and sink with mixing supply valve, and (4) the commercial clothes washer and dryer.

##### Potable Water Recovery Unit

The wick evaporator which was used during previous manned tests was operated in the open-cycle mode. In the open-cycle wick evaporator, urine processing is integrated with the humidity control, so that the only components required in addition to those already needed for humidity control are a urine evaporator and an air heater.

However, Space Station LSS trade-off studies indicate that a lower system penalty may be achieved utilizing a closed-cycle wick evaporator unit, for urine processing only, and a separate humidity control unit. Although each of these units will require separate blowers and condensers, the disadvantage of duplicate components is offset by the following advantages:

- o The interaction of the urine processing and humidity control functions is eliminated thereby simplifying both control loops.
- o Independent control provides more flexibility in cabin humidity level adjustments.
- o The wick evaporator may be operated at a higher air temperature thereby increasing the urine processing rate.
- o The isolation of the wick packages from the cabin atmosphere minimizes atmosphere contamination and improves microbial control in the wick evaporator.

Therefore, the present MDAC wick evaporator design will be modified for closed-cycle operation and the humidity control will be integrated with the thermal control unit.

In addition, improvements will be made in the potable water distribution loop to improve microbial control. Major emphasis will be directed to the development of a positive means of preventing bacteria contamination in the cold water dispenser, such as alternately heated heat exchangers, chlorine generators or iodine injection.

Provisions will be provided in this unit for the integration of the advanced subsystem electrolytic pretreatment unit. A schematic of the potable water unit is shown in Figure 3.

#### Wash Water Recovery Unit

The 90-day test unit will be modified to improve microbial control in the multifiltration module by minimizing heat loss and/or by the addition of heat to maintain the columns at approximately 339°K (150°F). Additional effort will include: (1) the development of a technique for processing and recovering water from dishwashing, (2) provisions for integration of the advanced subsystem zero-g shower, (3) the evaluation of potential cleansing agents for

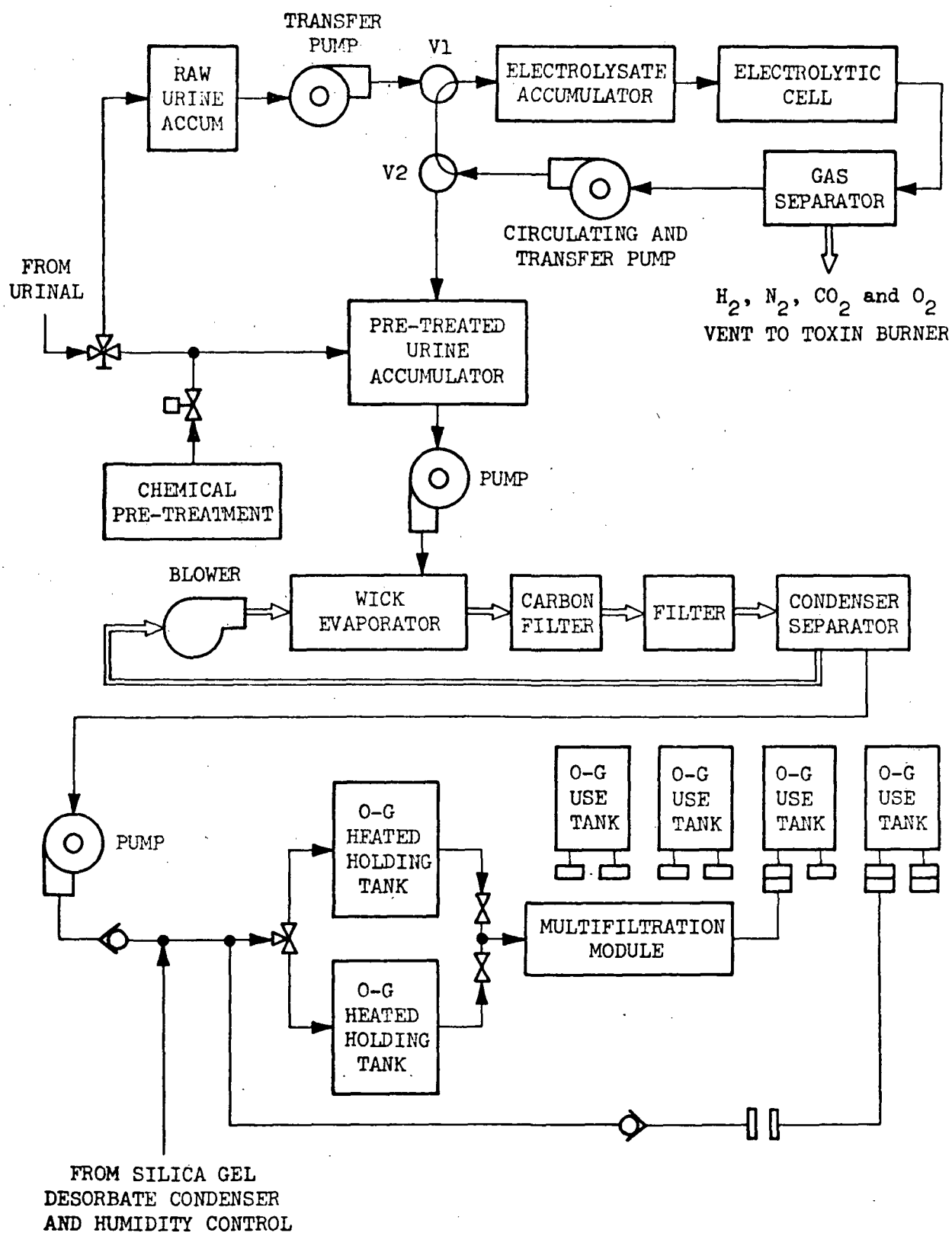


FIGURE 3 POTABLE WATER RECOVERY UNITS:

compatibility with system and crew, and (4) provisions for the integration of the advanced subsystem reverse osmosis unit. The 90-day commercial clothes washer and dryer will be retained for the Phase A test.

A schematic of the wash water recovery unit is shown in Figure 4.

#### 3.3.2.2 Atmosphere Control and Purification Subsystem

This baseline subsystem will consist of the thermal and humidity control unit, molecular sieve carbon dioxide concentrator, and the toxin control unit.

These units will be essentially identical to the units utilized during the 90-day test. The only major modification will be the integration of the humidity control with the thermal control as was noted in Section 3.3.2.1.

The integrated thermal and humidity control unit is shown in Figure 5, the molecular sieve carbon dioxide concentrator is shown in Figure 6, and the toxin control unit, which is integrated with the baseline Sabatier reactor, is shown in the upper portion of Figure 7.

#### 3.3.2.3 Atmosphere Supply and Pressurization Subsystem

This baseline subsystem consists of the Sabatier reactor, KOH wick electrolysis unit, and the flight-weight two-gas control unit.

The Sabatier reactor which was used during the 90-day test must be modified for operation with the proposed advanced subsystem hydrogen depolarized cell (HDC). In addition, a carbon filter will be installed in the cooling air loop to protect the integrated toxin burner catalyst from trace contaminants. A flight-type Sabatier reactor will be installed as an advanced subsystem for the Phase A test and the toxin control portion only will be operated continuously with the Sabatier reactor in standby. A schematic of the baseline Sabatier reactor is shown in Figure 7.

The baseline water electrolysis unit will be KOH electrolyte unit utilizing either the static vapor feed or circulating electrolyte techniques.



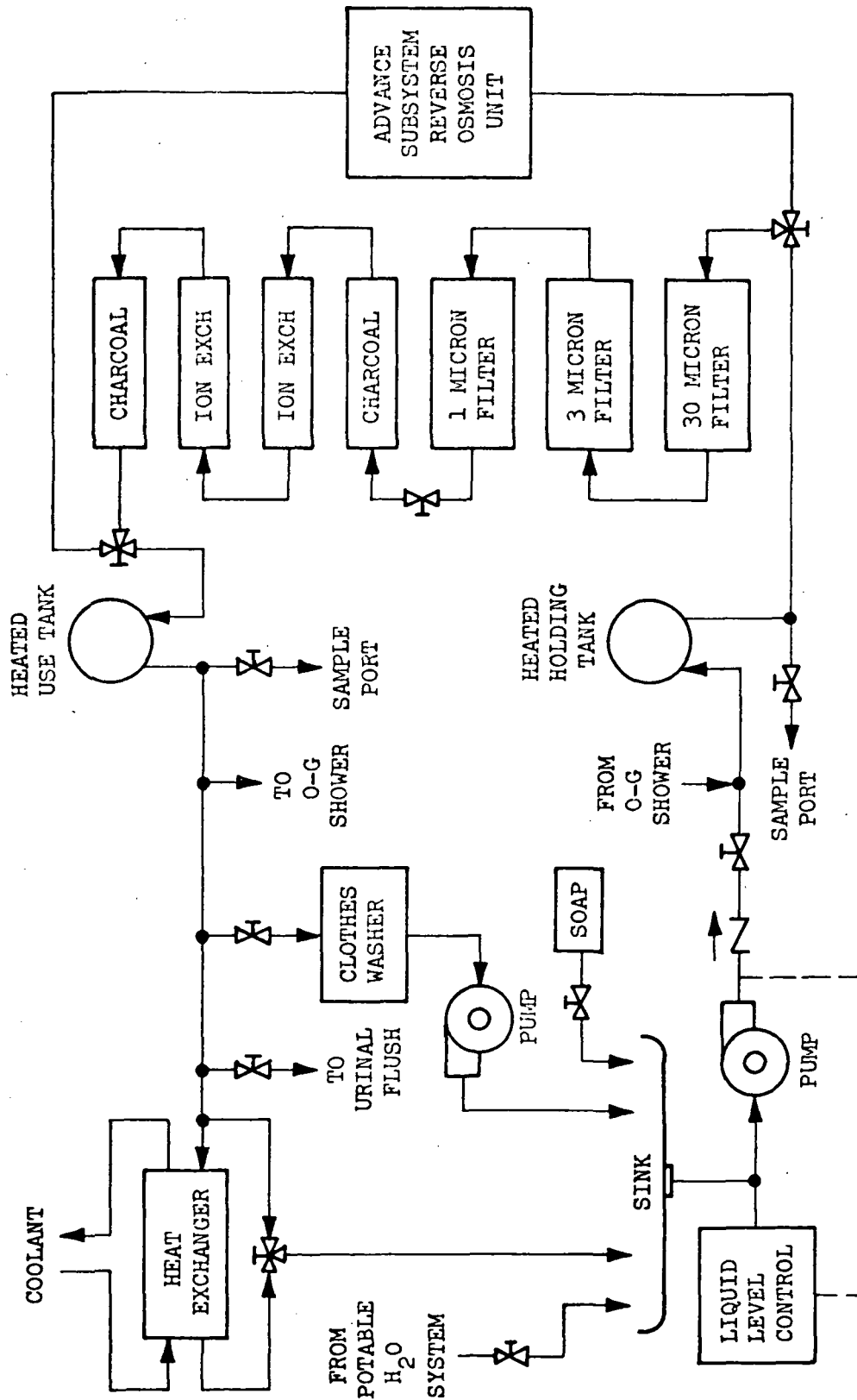


FIGURE 4 WASH WATER RECOVERY UNITS

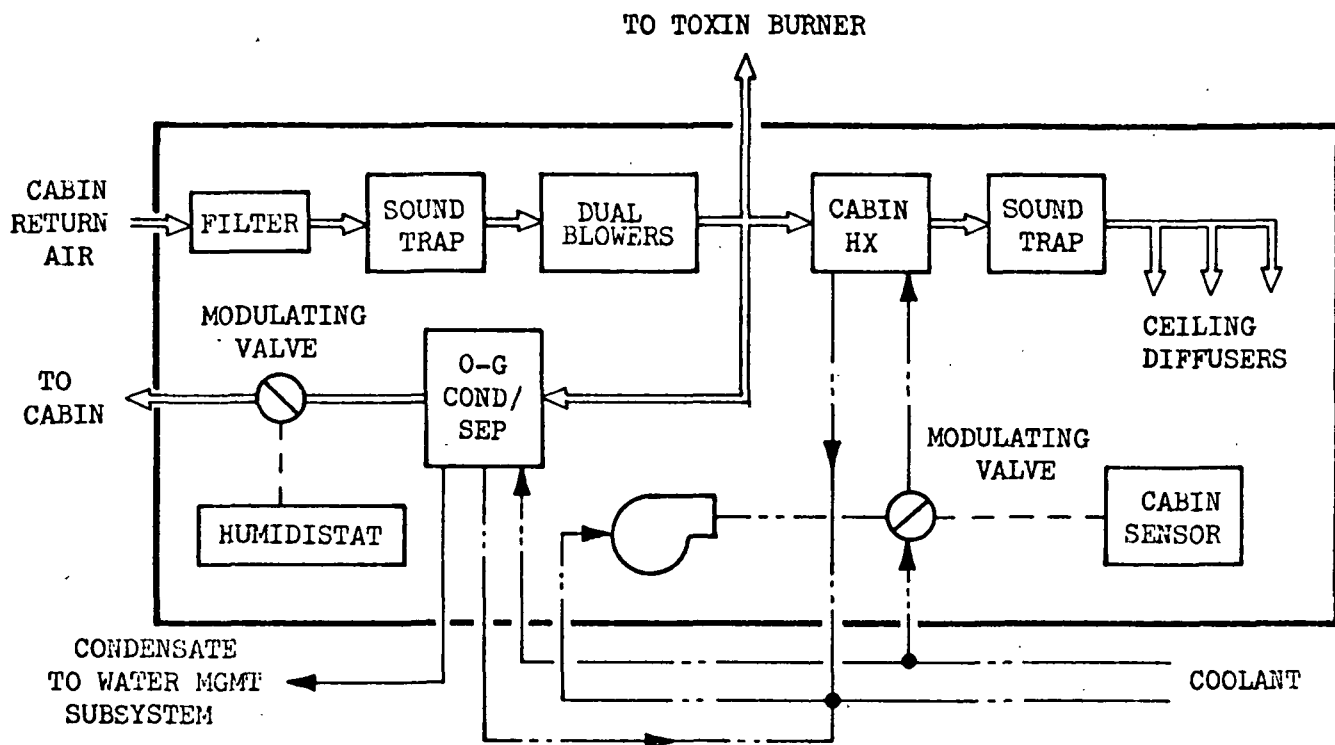


FIGURE 5 THERMAL AND HUMIDITY CONTROL UNIT SCHEMATIC

Electrolysis units utilizing each of these techniques were evaluated during the 90-day test. The static vapor feed unit has been extensively redesigned by MDAC and will be evaluated in comparison with a circulating electrolyte unit developed by the Lockheed Missiles and Space Company. This competitive test will be conducted under NASA Contract NAS9-12048 and scheduled to be completed by July 1972, with the most successful unit from this test to be recommended for the Phase A test as a baseline unit.

Schematics of the two water electrolysis units tested during the 90-day test are shown in Figure 8 and 9. The redesigned units to be evaluated will be similar.

The baseline two-gas control will be essentially identical to the unit evaluated during the 90-day test. This unit will again be integrated with the Perkin-Elmer mass spectrometer sensor for  $O_2$  and  $N_2$  control. A polarographic partial pressure  $O_2$  sensor and strain-gage absolute pressure transducer will be provided as backup for the mass spectrometer. A schematic of this unit's operation is shown in Figure 10.



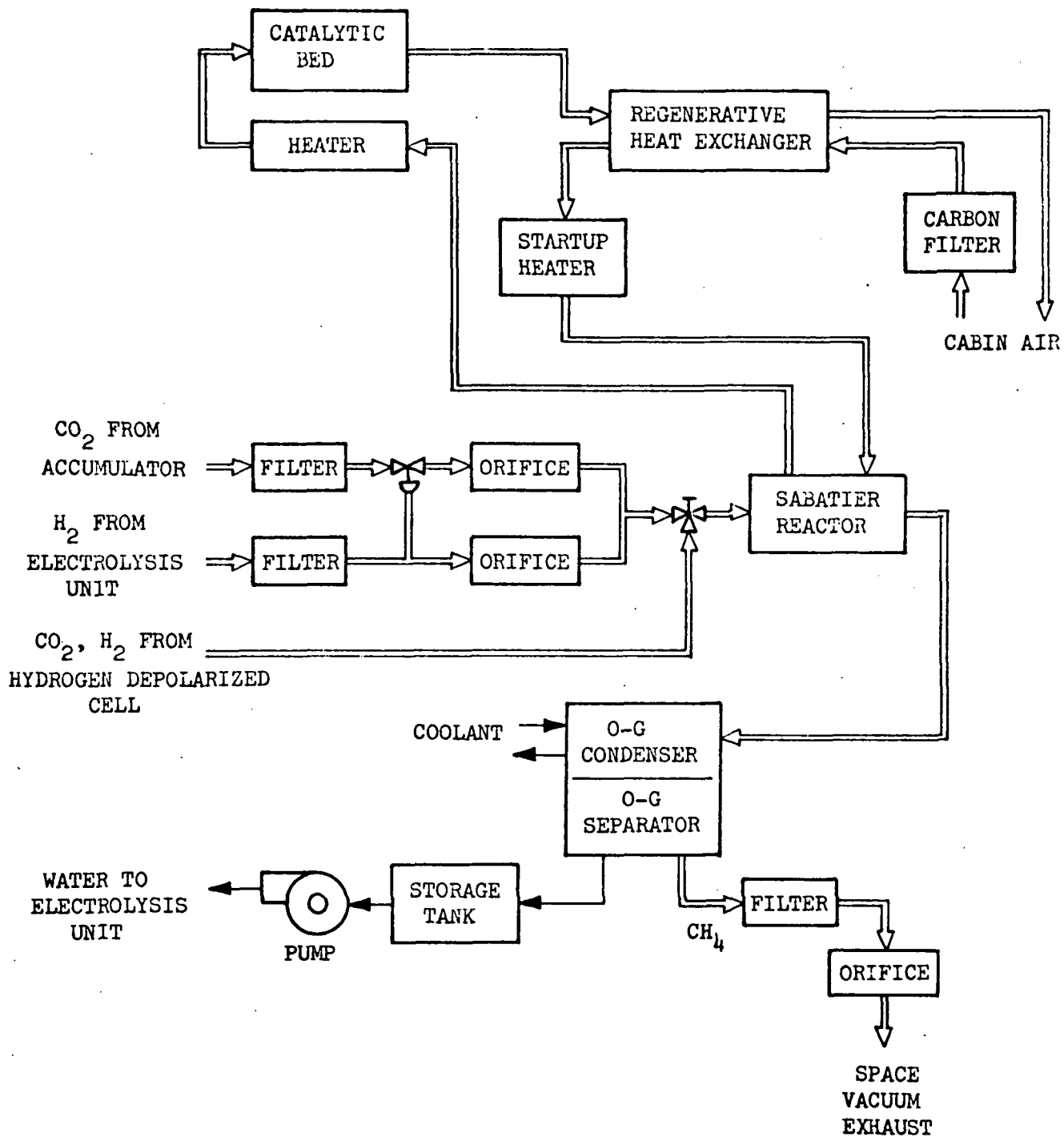


FIGURE 7 INTEGRATED SABATIER AND TOXIN CONTROL

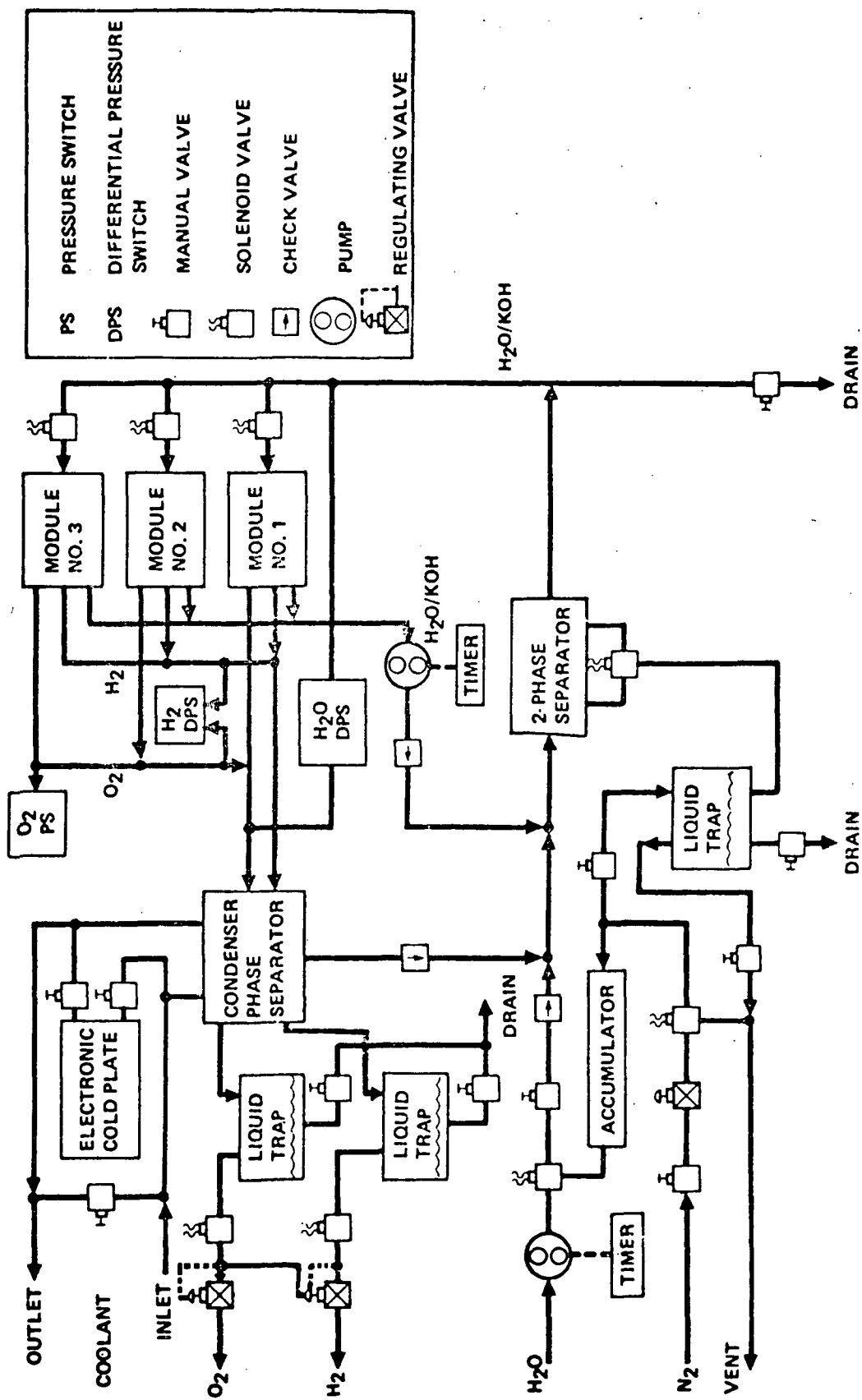


FIGURE 8 STATIC VAPOR FEED WATER ELECTROLYSIS UNIT

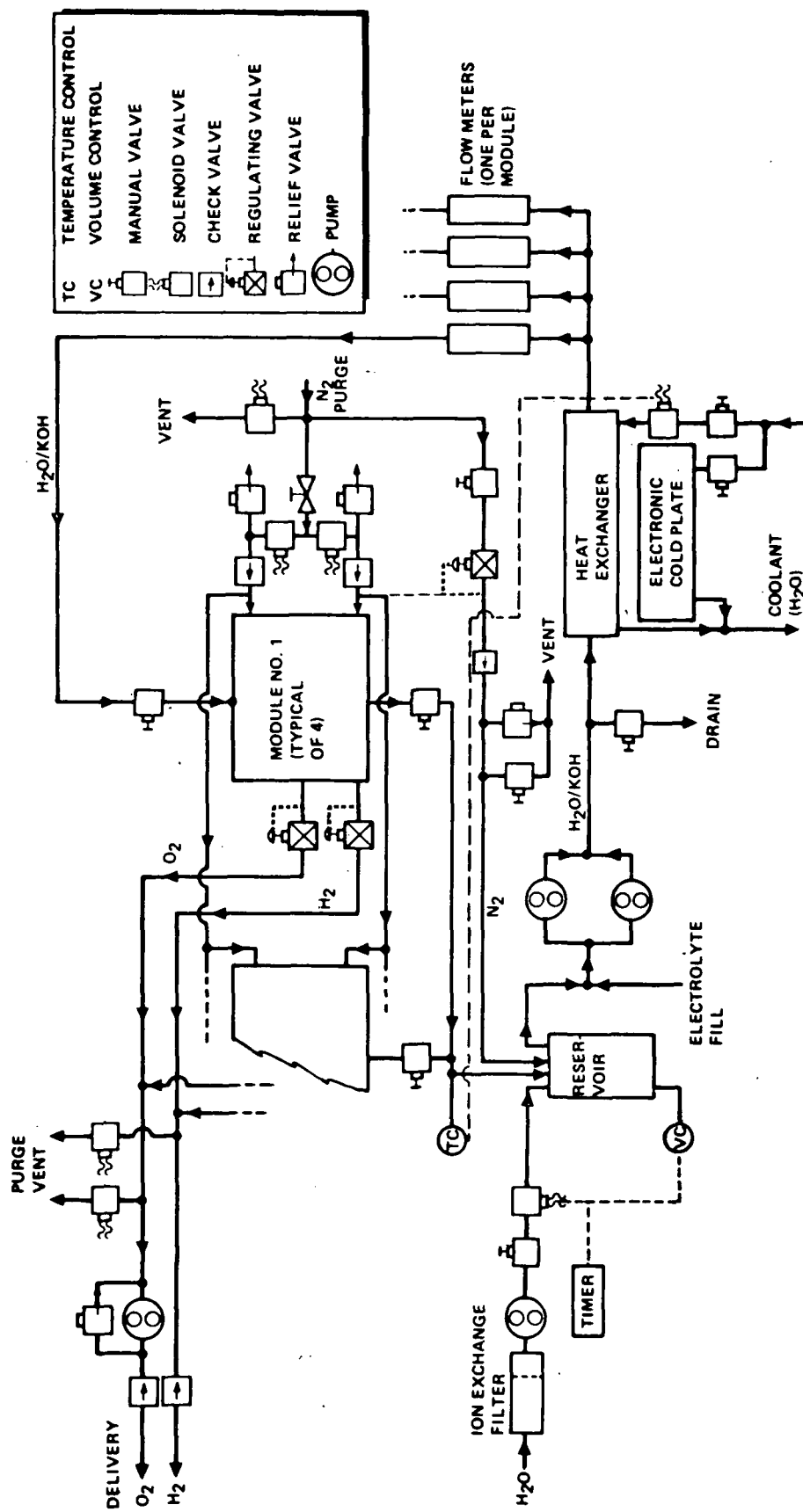


FIGURE 9 CIRCULATING ELECTROLYTE WATER ELECTROLYSIS UNIT

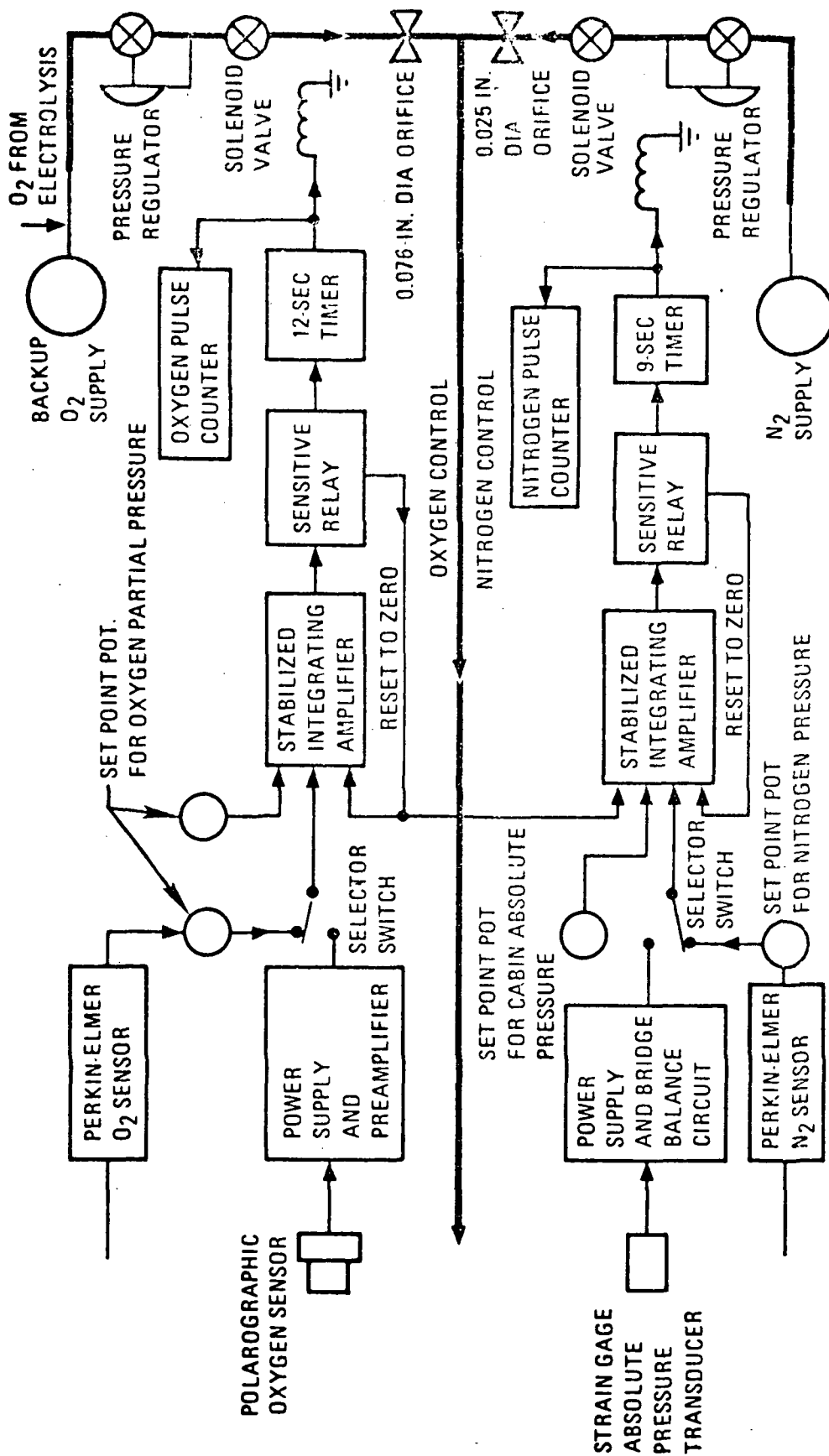


FIGURE 10 TWO-GAS CONTROL

### 3.3.2.4 Waste Management Subsystem

The baseline waste management subsystem will consist of the General Electric-developed "Dry John" commode and the prototype Skylab A urine separator.

The commode is the same unit which was used during the 90-day test. The integration of this commode and the Skylab A/Shuttle zero-g urine separator is shown schematically in Figure 11.

### 3.3.3 Integration of the Life Support System (LSS)

The integration of the major components of the baseline and advanced subsystems for the Phase A test are shown in Figure 12. The integration of the two advanced subsystems for the Phase B test cannot be defined at this time since the selection of life support equipment is dependent on the results of the Phase A test. Therefore, this discussion will cover only the Phase A ISS interface requirements. Since the complete definition of the advance/baseline subsystems interface will require additional

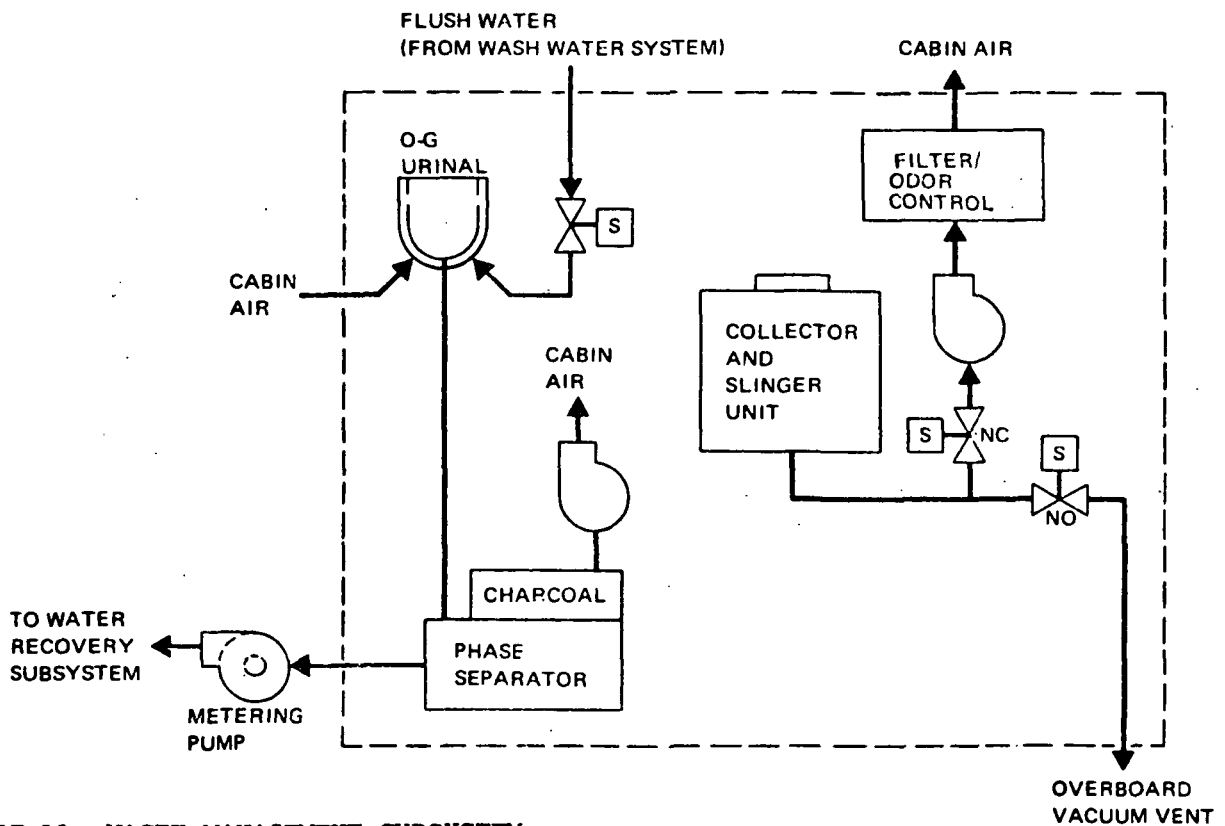
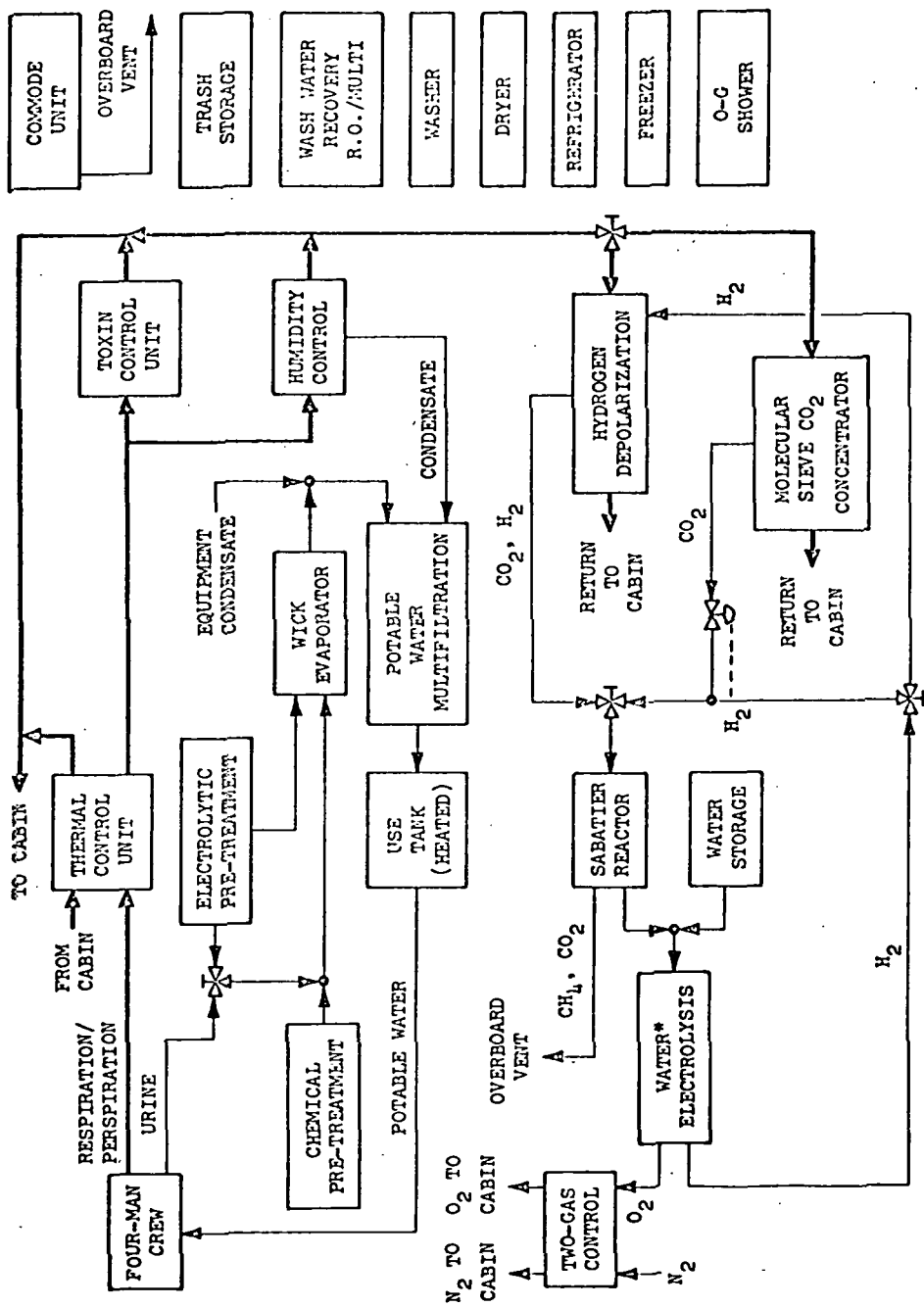


FIGURE 11 WASTE MANAGEMENT SUBSYSTEM





\*SCHEMATIC IDENTICAL FOR KOH AND SOLID POLYMER UNITS

FIGURE 12. LIFE SUPPORT SYSTEM BLOCK DIAGRAM (ALL EQUIPMENT NOTED INSTALLED WITHIN CHAMBER)

coordination with the suppliers and cognizant NASA agencies, this discussion will only attempt to cover generalized interface requirements, some possible integration approaches, and potential problem areas.

#### 3.3.3.1 Water Management

The baseline closed-cycle wick evaporator will be integrated with the advanced subsystem electrolytic pretreatment unit, with chemical pretreatment as a backup as was shown in Figure 3. This configuration will provide valuable engineering test data for the Phase B test candidate electrovap unit, discussed in Section 3.3.1.1 previously.

The integration of the advance subsystem and the baseline water recovery units was not shown in Figure 12 for simplicity. The vapor compression and RITE water management units are candidate advanced subsystems for the Phase A test. Two vapor compression modules are planned for the SSP program; one module processing pretreated urine and flush water and the second module processing the concentrated brine, from the reverse osmosis wash water unit, and fecal flush water, from the commode. Since the SSP/Shuttle advanced subsystem commode and an advanced subsystem reverse osmosis wash water unit are recommended for inclusion in the Phase A test, the advanced subsystem water management unit should be integrated into the LSS in a configuration which would permit evaluation in both operating modes. A method for accomplishing this evaluation and at the same time obtaining valuable data on the wick evaporator unit is shown in Figure 13.

In the recommended approach (Figure 13) each unit would be operated using the two types of waste water for two weeks, or half of the total Phase A test period. In this manner, each unit would operate for the entire 4 weeks, 2 weeks on each type of waste water, rather than operating the advanced subsystem unit only with the wick evaporator in standby. With this approach, valuable data would be obtained on both units in two modes of operation and on the electrolytic pretreatment unit operation with two water recovery techniques. In the event of a malfunction of either unit, the other unit would provide adequate backup while repairs were accomplished.

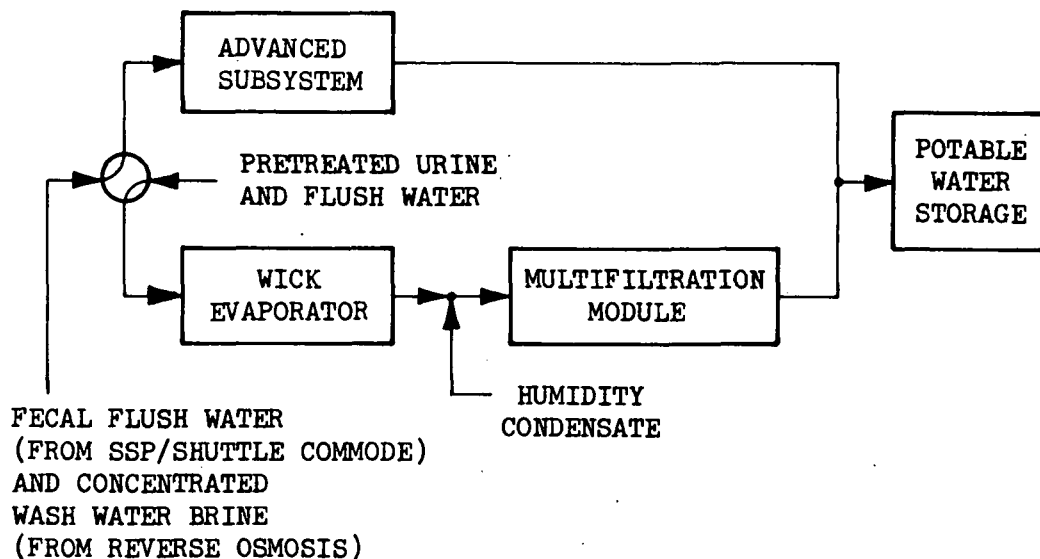


FIGURE 13 INTEGRATION OF THE ADVANCED SUBSYSTEM  
AND WICK EVAPORATOR UNITS

The advance subsystem reverse osmosis unit will be integrated in parallel with the baseline multifiltration unit as shown previously in Figure 4. The detail integration of this unit cannot be determined until more design information is available. If a hybrid reverse osmosis/multifiltration unit is developed for the Phase A test, the concentrated brine could be routed into a multifiltration module upstream of the reverse osmosis cell, rather than into the advanced subsystem or wick evaporator units, as discussed above. However, in order to obtain the most information on the advanced subsystems, it is recommended that the concentrated brine be processed in the potable water recovery units with the multifiltration mode of operation as backup. The baseline multifiltration wash water unit will be in a standby mode to back up the reverse osmosis unit.

The advance subsystem zero-g shower schematic is shown in Figure 14. This unit would be integrated into the wash water recovery units as previously shown in Figure 4. Backup for this unit would be provided by sponge bathing as was done in the 90-day test.

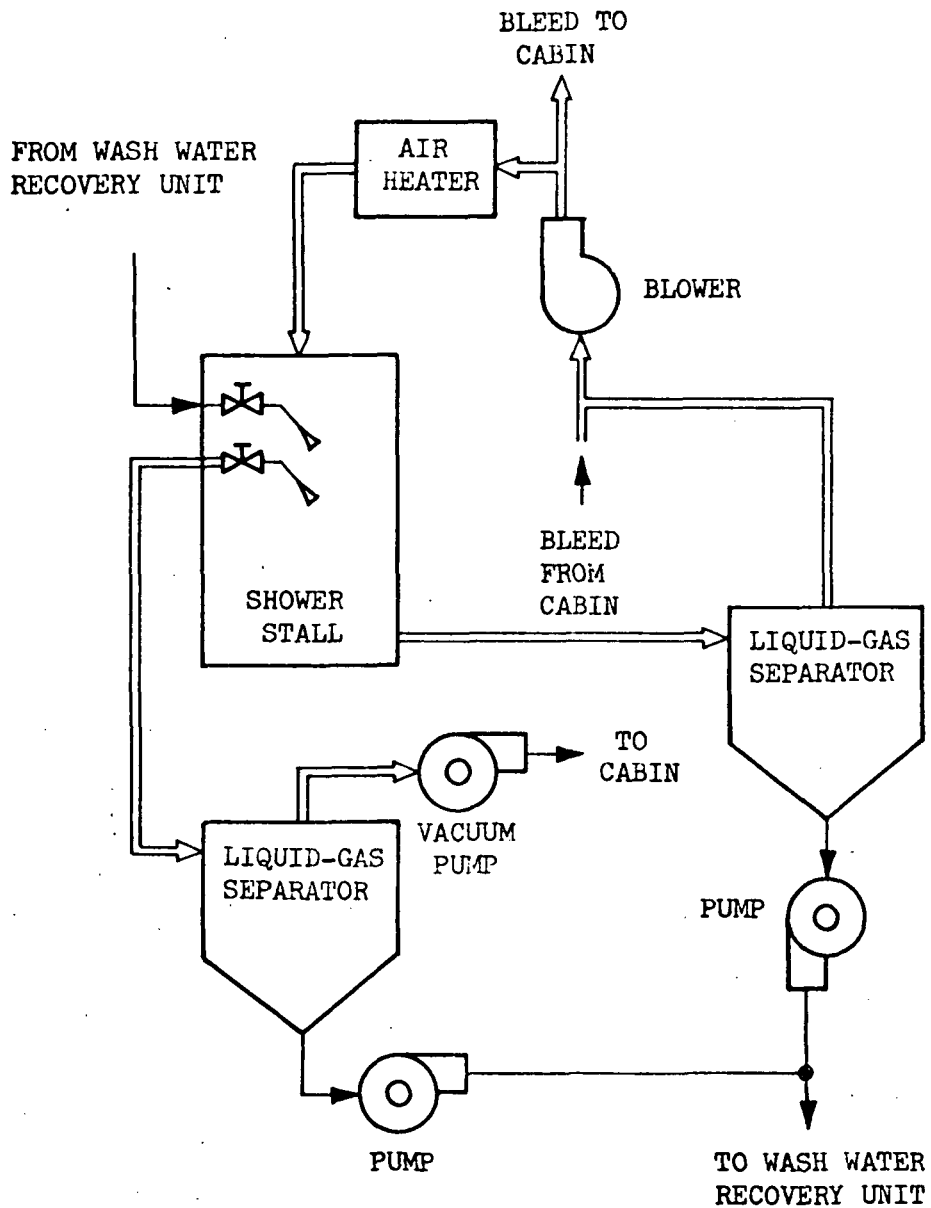


FIGURE 14 ZERO-G SHOWER

### 3.3.3.2 Atmosphere Control and Purification

The advance subsystem hydrogen depolarized cell (HDC) will be integrated into the LSS as shown in Figure 12 with the baseline molecular sieve concentrator as backup. A schematic of the unit is shown in Figure 15.

There is a significant difference in the method of delivery of carbon dioxide, to the Sabatier reactor, by the HDC and the baseline concentrator.

The HDC delivers the carbon dioxide premixed with hydrogen at essentially cabin pressure whereas the baseline unit delivers carbon dioxide at pressures significantly higher than cabin pressure, which must be mixed with hydrogen at the Sabatier reactor. This difference in interface requirements will require the incorporation of two Sabatier reactor control techniques which are discussed below in Section 3.3.3.3.

The temperature, humidity, and toxin control functions will be controlled by the baseline units discussed previously in Section 3.3.2.2. Since these units are essentially modified 90-day units, their integration should pose no additional problems for the Phase A test.

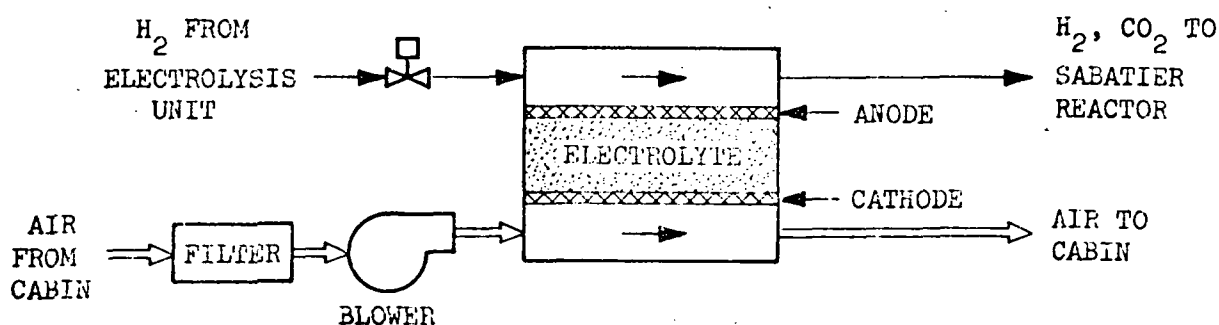


FIGURE 15 HYDROGEN DEPOLARIZED CELL

### 3.3.3.3 Atmosphere Supply and Pressurization

The installation of the advance subsystem flight-type Sabatier reactor would be similar to the baseline installation shown previously in Figure 7 without the integration of the toxin control in the cooling loop. As previously noted in Section 3.3.3.2, the integration of the HDC and baseline carbon dioxide concentrators will result in gaseous feed control incompatibilities with the Sabatier reactor. These control incompatibilities will be identical for both the advanced and baseline subsystems. In addition to the differences in the gaseous feed interface shown in Figure 7, a back-pressure regulator, or other pressure control technique, would replace the fixed orifice reactor pressure control for operation at the lower HDC pressure and variable gas flow rates. The detail control design and interfaces must be coordinated with the supplier of the HDC and flight-type Sabatier reactor.

A schematic of the advanced subsystem solid polymer electrolyte (SPE) water electrolysis unit is shown in Figure 16. It is recommended that, due to space limitations and past experience, the SPE water electrolysis unit be installed outside the test chamber. However, the SPE unit will be integrated in parallel with the onboard baseline unit and utilize the same Sabatier-produced water to supply oxygen and hydrogen to the cabin, thereby maintaining closed-chamber operations. This recommendation is made based on the 90-day test experience where the onboard water electrolysis unit failed early in the test and, since this unit was not accessible to highly qualified personnel, could not be repaired. The outside unit was accessible for complete rebuilding of modules when required and, in spite of serious malfunctions, operated for 70 of the 90 days. The development of advanced concepts of water electrolysis has proven in the past to require extensive bench testing prior to manned tests. Due to the limited time available prior to the recommended start of the Phase A test, it is doubtful that adequate bench testing of the SPE unit could be accomplished. This concept should be re-evaluated if SPE bench tests reveal significant faults or if the Phase A start is postponed.

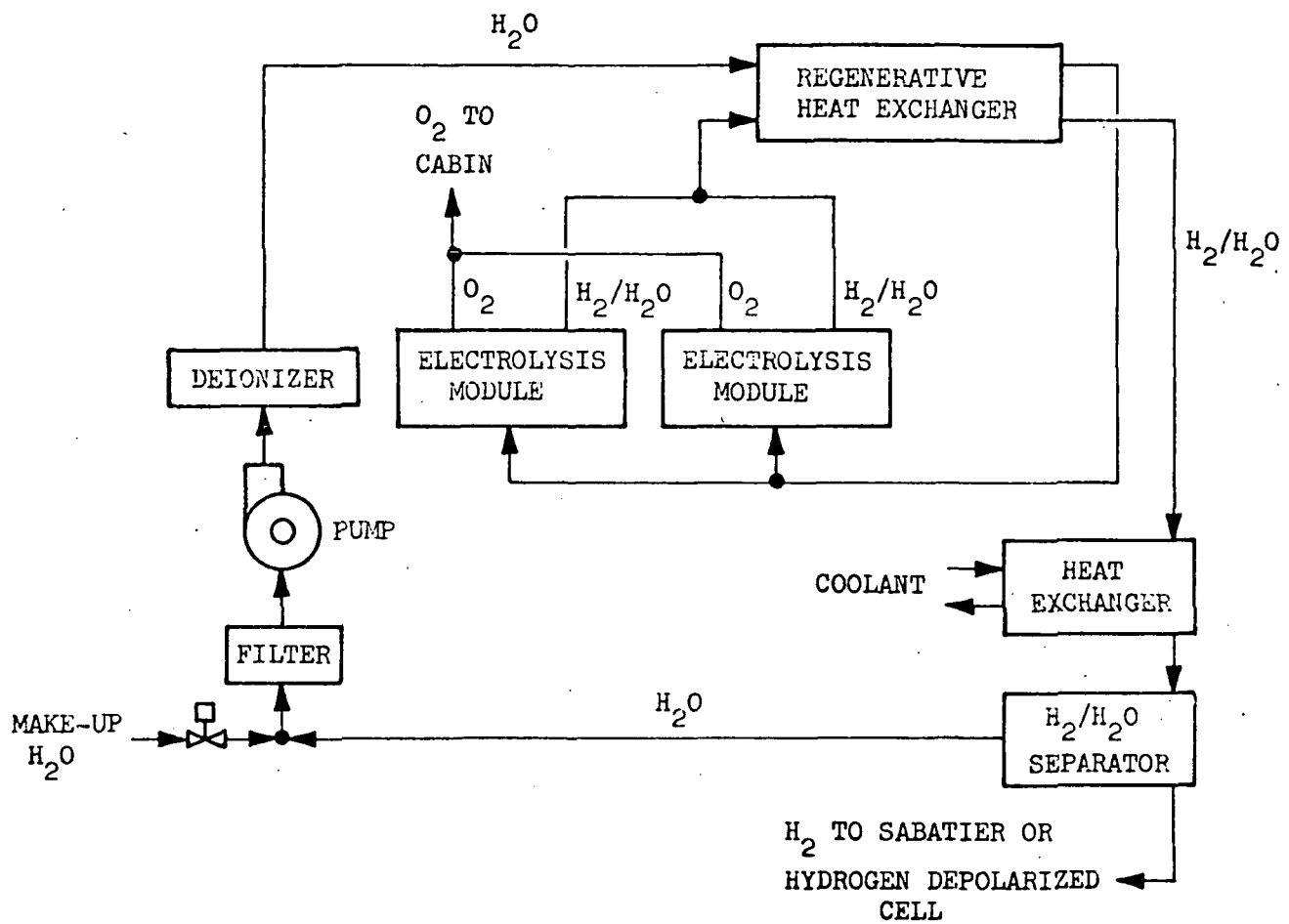


FIGURE 16 SOLID POLYMER ELECTROLYTE WATER ELECTROLYSIS UNIT

The flight-type two-gas control and mass spectrometer sensor will be essentially identical to the units utilized during the 90-day test. The integration of these units should pose no additional problems for the Phase A test.

#### 3.3.3.4 Waste Management

The waste management subsystem for the Phase A test will consist of the SSP/Shuttle commode and the Skylab A/Shuttle urine collector. The advanced subsystem SSP/Shuttle commode will be similar to the baseline commode shown previously in Figure 11. However, as noted in the discussion of water management (Section 3.3.3.1), this unit contains an anal flush feature and this waste water must be processed in the potable water recovery unit.

The only integration problem anticipated in the waste management area will be lack of space in the chamber for both the advanced subsystem and baseline commodes. The 90-day test was conducted with only one commode, with backup provided by onboard spares. The decision to conduct the Phase A test with one or two commodes will be made after design evaluation and coordination with the supplier.

#### 3.3.4 Evaluation of Non-Life Support Equipment

Three add-on engineering experiments have been identified and recommended for the Phase A test. These are the evaluation of: (1) a biowaste resistojets utilizing the Sabatier reactor exhaust gases, (2) a damage control system for detection of spacecraft leakage utilizing the two-gas control unit, and (3) an onboard LSS checkout system. Potential engineering experiments for the Phase B test will be identified after an evaluation of the Phase A test results.

A biowaste resistojets system design is described in Reference 3. This study shows that substantial weight savings may be achieved by the utilization of the excess biowastes from the Sabatier reactor as propellant in a low thrust resistojets for vehicle attitude control. The Sabatier/resistojets interface equipment is presently being developed under NASA Contract NAS1-10961 and, as discussed in Section 3.3.1.1, will be available for the Phase A test.



A study of damage control systems for manned spacecraft was recently completed under NASA Contract NAS1-10184. One concept recommended for further study was a two-gas atmosphere pulse-rate modulated controller which would monitor cabin gas leakage. In addition to its primary function of regulating the partial pressure of oxygen and nitrogen in the cabin, the controller supplies nitrogen pulse rate data as a measure of overboard leakage. The present two-gas controller, which is proposed for the Phase A test, could be modified to provide this function and would provide valuable data for the development of future damage control systems.

The development of LSS onboard checkout and automatic control will be important to future manned spacecraft design. At present, the life support equipment on the Apollo and Skylab programs is in close enough proximity to the crew to allow manual operation. As spacecraft become more sophisticated, this ability to monitor the LSS manually will become more difficult and create a requirement for remote sensing and control. The extended manned test program will provide an excellent opportunity for economically studying methods and techniques in an operational environment. A plan for implementing this experiment is discussed below in Section 3.3.5.

The baseline program for the Phase A test will include direct centralized monitor and alarm of initial LSS parameters and will provide a demonstration of subsystem automation. However, it is felt that more sophisticated approaches to these functions will be desirable, as well as incorporation of fault isolation techniques. The computer hardware to accomplish these functions will be available but additional software development will be needed for complete evaluation of possible techniques. Development of this software is recommended as an add-on experimental task.

### 3.3.5 Preliminary Plan for Life Support System Automation

A study was made to determine the feasibility and level of computerized automatic control which would be beneficial in improving LSS performance. The scope of computerized automatic control (applied to LSS) considered ranged from subsystem functions to operation of all units in an integrated mode under computer direction. Experiment recommendations for both Phase A and Phase B tests is shown in Table 6.

TABLE 6. CANDIDATE SUBSYSTEM FUNCTIONS FOR COMPUTER CONTROL

SUBSYSTEM	Test Phase A				Test Phase B			
	Controlled Function	Type of Control	Programmed Method of Control	Comments	Controlled Function	Type of Control	Programmed Method of Control	
Sabatier	Reactor Heater	Two-Position (on-off)	Computer monitors feed-back from three (3) thermocouples on reactor bed	Highly useful function. Recommended based on past tests.	Mixture ratio and reactor cooling	Modulating	Computer monitors H <sub>2</sub> pressure and reactor temperature	Combined v/reactor heater control this would offer complete unit control
Two-Gas	Adjustment of O <sub>2</sub> and N <sub>2</sub> setpoints	Modulating	Computer monitors cabin total pressure and O <sub>2</sub> partial pressure over extended time period prior to making set-point adjustment	Computer could monitor trend and indicates when crew should adjust set-point				
Potable Water	Pasteurizing time and tank transfer	Two-Position	Computer times heat cycle, monitors temperature and transfers potable water from holding tank to use tank	Not recommended as a computer control function				
Wash Water	Sterilizing time and multi-filter-ation process	Two-position	Computer times heat cycle, monitors temp. and transfer wash water (high rate initially - then reduces to a lower transfer rate).	Useful function which would reduce crew time and provide record of process completion				
Electrolysis	Cell shutdown	Two-position	Computer monitors voltage and current for excess levels	Recommended				
	Current Controller	Modulating	Computer monitors current, O <sub>2</sub> accumulator pressure and use rate	Recommended - should reduce size of O <sub>2</sub> accumulator				
CO <sub>2</sub> Concentration	Bed switching	Two-position	Computer monitors breakthrough for optimum bed switching	Should improve unit operation				
Simulator Support	Peak power	Two-position	Computer monitors power demand and establishes priority for each component	Would reduce peak power required				
Electrolysis					Wick feed rate condenser coolant flow rate and air flow rate	Modulating	Computer monitors air saturation, wick water content air flow, and air temperature	Computer control would aid in optimizing the unit.

The experiment recommendations shown in Table 6 reflect limited scope and complexity based on a precept of minimum funds for design, hardware procurement and software development. However, much experience and information can be obtained which will provide a basis for more detailed evaluation of the requirements for computer automatic control if the experiments are incorporated in the extended manned test program.

In definition of automation requirements, it was felt that a basic responsibility of the subsystem manufacturer is to provide automation at the lowest practical level as a general philosophy. Thus direct control of temperature by using a thermostat to control heat input is preferable to incorporation of all such functions into a central computerized control system. This is consistent with general control system philosophy which postulates that the simplest, most direct feedback loop will be the most effective and reliable. It is also in accord with a requirement imposed during the life support system design portion of the study: that the system operation must be essentially unaffected by failure of the computer. This latter may not be necessary in flight systems where adequate redundancy in computer equipment will insure continuous operation but is surely true for the planned extended test. The function of overall computer control is, therefore, one in which set-point adjustments are made upon regulating functions internal to a unit, achieving an overall improvement in system efficiency; where computerized functions can be used to reduce the requirement for manual surveillance or adjustment; or where the computer control can be used to augment the reliability of an internal control function, presumably by sensing and controlling upon a combination of parameters.

Numerous computers are adaptable for tasks similar to LSS processes. However, only four (4) machines were reviewed in depth. They were:  
1) Fisher DC<sup>2</sup>, 2) ALGO 16, 3) CDC 8090 and 4) XDS 930.

Fisher DC<sup>2</sup> - This is a modular designed computer compatible with a special language called PC<sup>2</sup>. It has a memory capacity of 4,096 words to 16,384 words of read/write storage. The machine could be built to meet a predefined automatic control task but would lack flexibility in changing control functions.

ALGO 16 - This machine is a modular designed direct digital control data handling system. The digital processor has a basic core memory of 8,192 binary words (12 bits) which is expandable to 32,768 words. It is capable of handling a closed-loop control program which receives data, computes corrective action information and outputs the corrective action to the final control elements. This machine lacks real growth capability for future tests and would be slow when doing data conversion, status and alarm, and system performance calculations in addition to the automatic control function.

CDC 8090 - This machine does not have the capability for complex control. It is limited in capacity and is programmable in a machine language which lacks flexibility and growth potential. It is more suited to the status and monitor functions.

XDS 930 - This machine utilizes a higher level language (FORTRAN) and has the capacity to handle other on-line real time functions while performing the control aspects. Without question it offers more potential in growth and capacity than other machines considered.

Either the Fisher or ALGO 16 computer would probably be perfectly adequate to perform a demonstration of automation concepts such as outlined in Table 6. However, both machines are very limited in capability and certainly would not be able to perform the data collection and reduction, discussed in Section 3.8, nor would they be able to perform the required monitor and alarm function unless considerable preprocessing equipment was added at the subsystem level to perform internal checking and editing functions. Such preprocessors or interface units may be provided as a part of the advanced subsystems but would be uneconomical to add to the baseline units, where they would also be required. A further apparent disadvantage of the Fisher DC<sup>2</sup> computer is that its programming is not readily changed. For a development program in which inadequate definition of operating characteristics is the rule, this lack of flexibility is not acceptable.

The data management system discussed in Section 3.8 proposes to use the XDS 930 computer or equivalent for data collection, manipulation, and display. The CDC 8090 computer is used for monitor and alarm functions and, therefore, unloads the XDS 930 of much interim activity unless pre-set limits are exceeded by a critical parameter. Since this equipment is in use for these functions, and is philosophically similar to the "Data Bus" systems proposed for flight application, it is believed that the best method of demonstrating system automation is by supplying modifications to hardware and programs necessary to implement one or more of the recommendations of Table 6. The programs could be derived from those presently being developed for the CVT by NASA-MSFC and will not, of course, be similar to the existing G189 design program, although control algorithms may be developed from subroutines of the G189.

#### 3.4 TEST FACILITY DESIGN REQUIREMENTS

This section describes the test facilities required for the extended manned test program for the Phase A test. Minor modifications should be made to the existing simulator and facilities utilized during the 90-day test. For the Phase B test a new expanded chamber with capability for a 6 man crew has been evaluated. Its implementation is questionable, however since the benefits do not appear to justify the cost. The requirements for modifications and new facilities are discussed in the following paragraphs.

##### 3.4.1 Elimination of Mass Transfer Into or Out of the Chamber

A major goal of this extended manned test program will be the elimination of all mass transfer into or out of the test chamber. A primary mission objective of the recently completed 90-day test was that all expendables were to be stored on-board with no pass-in during the test. The accomplishment of this objective was a major achievement of the 90-day test. However, pass-outs were required of medical and engineering samples for analysis by outside laboratories. In addition, venting of certain materials by the LSS was required. The minimizing or elimination of these sample and venting requirements will require modifications to the facilities and procedures.

A summary of the liquid transfer overboard during the 90-day test is presented in Table 7. A majority of these transfers were required for water and urine analysis and water discarded overboard during periods of LSS operational problems. The requirements for analysis samples will be eliminated by the availability of the onboard laboratory for biomedical and water analysis. This laboratory is described in Section 3.4.2.

During the 90-day test it was necessary to discard some water and urine which had accumulated during periods of water processing equipment down time (e.g.: The urine collector, the VD-VF boiler, and solid amine condenser.). Operating procedures for future tests will require the processing of all water thereby eliminating this transfer.

The overboard transfer of water by venting of life support equipment cannot be eliminated for the Phase A test since non-venting oxygen recovery and waste management equipment will not be available. Assuming that the daily averages on Table 7 are applicable to the Phase A commode and Sabatier reactor, the overboard transfer of water can be reduced to 0.39 Kg/day (0.86 lb/day) from 1.60 Kg/day (3.53 lb/day). Additional reductions in the Sabatier losses can be realized if the condenser exhaust dew point is reduced from the 344°K (160°F) measured during the 90-day test. This saving can be achieved by installing a condenser with adequate heat transfer surface for the Phase A test.

A summary of the gas transfer overboard during the 90-day test is presented in Table 8. The requirements for gas analysis sampling during the Phase A test is estimated to be approximately 3.0 liters/day. Although Sabatier venting cannot be eliminated for the Phase A test, these exhaust gases may be utilized in the resistojet experiment discussed in Section 3.3.4. The venting of the hydrogen and carbon dioxide accumulator during the 90-day test were required during evaluation of equipment problems, such as the operation of the Sabatier reactor with bottled gas during the investigation of catalyst poisoning. Although this venting may not be eliminated in future test, it can be minimized by improvements in equipment and procedures.

Table 7  
SUMMARY OF LIQUID TRANSFER OVERBOARD - 90-DAY TEST

Source	Totals Kg (lb)	Daily Average Kg/Day (lb/Day)
<hr/>		
Samples:		
Potable Water	26.61 (58.6)	0.295 (0.650)
VD-VF Condensate	5.99 (13.2)	0.066 (0.147)
Wash Water	3.36 ( 7.4)	0.037 (0.082)
Urine	10.94 (24.1)	0.121 (0.268)
Blood	2.70 ( 5.9)	0.030 (0.066)
Subtotal	49.60 (109.2)	0.549 (1.213)
Discarded Overboard:*		
Potable Water	25.25 (55.6)	0.280 (0.617)
VD-VF Condensate	0.82 ( 1.8)	0.009 (0.020)
LSS Condensate	4.50 ( 9.9)	0.050 (0.110)
Wash Water	4.40 ( 9.7)	0.049 (0.108)
Urine	1.14 ( 2.5)	0.013 (0.028)
Subtotal	36.11 (79.5)	0.401 (0.883)
Water Vapor Vented Overboard		
VD-VF	23.43 (51.6)	0.260 (0.573)
Commode	23.70 (52.2)	0.263 (0.579)
Sabatier	11.40 (25.2)	0.127 (0.280)
Subtotal	58.53 (129.0)	0.650 (1.432)
Totals	144.24 (317.7)	1.600 (3.528)

\*Due to operational problems.

Table 8  
SUMMARY OF GAS TRANSFER OVERBOARD - 90-DAY TEST

Source	Totals Kg (lb)	Daily Average Kg/Day (lb/Day)
Gas Analysis Samples:		
CO <sub>2</sub>	0.08 (0.17)	0.0009 (0.0019)
N <sub>2</sub>	1.04 (2.30)	0.0115 (0.0255)
O <sub>2</sub>	0.50 (1.10)	0.0056 (0.0122)
Subtotal	1.62 (3.57)	0.0180 (0.0396)
Vent Overboard:		
Sabatier Exhaust:		
CH <sub>4</sub>	69.24 (152.50)	0.7686 (1.6928)
CO <sub>2</sub>	98.79 (217.60)	1.0966 (2.4154)
N <sub>2</sub>	7.55 ( 16.62)	.0838 (0.1845)
O <sub>2</sub>	0.23 ( 0.50)	.0026 (0.0056)
H <sub>2</sub>	1.73 ( 3.80)	.0192 (0.0422)
Subtotal	177.54 (391.02)	1.9708 (4.3405)
Hydrogen Accumulator*	7.08 ( 15.60)	0.0786 (0.1732)
CO <sub>2</sub> Accumulator*	68.60 (151.10)	0.7615 (1.6772)
Subtotal	75.68 (166.70)	0.8401 (1.8504)
Leakage:**		
N <sub>2</sub>	116.32 (256.20)	1.2912 (2.8438)
O <sub>2</sub>	57.34 (126.30)	0.6365 (1.4019)
Subtotal	173.66 (382.50)	1.9277 (4.2457)
Totals	428.50 (943.79)	4.7566 (10.4762)

\* Due to operational problems.

\*\* Includes venting of commode, VD-VF, trash container, and other miscellaneous items.



As noted in Table 8, the leakage during the 90-day test included the venting of the commode, VD-VF, trash container, and other equipment. These quantities were not recorded separately and must be recorded or eliminated in future tests. Since a non-venting commode is not available for Phase A, this venting requirement must be recorded. It is recommended that, in addition to recording the water collected in the cold traps, the gas flow be measured and the gas composition be analyzed during the test. In addition, the water collected must be chemically analyzed for trace contaminants.

The venting for the VD-VF and trash container can be eliminated, since the VD-VF is not included in the Phase A test and the trash container will not be vented to the annulus. Any venting of the trash container will be to the cabin through a carbon filter. Solid trash which might generate excess gases will be canned and autoclaved. If any cans bulge they will be stored in the freezer.

The venting of any equipment must be minimized or eliminated by careful design integration. As any example, during the 90-day test, the pneumatic pressure for the zero-g bladder tanks was provided by a separate gaseous nitrogen source which was vented to the annulus. This equipment may be replaced with an onboard compressor/accumulator system which provides pressurized cabin atmosphere to the bladder tanks and other equipment requiring pneumatic pressure.

The cabin leakage cannot be eliminated but can be reduced by improvements in design. In addition, the inclusion of the damage control experiment, discussed in Section 3.3.4, will assist in locating any abnormal leakage caused by equipment malfunction or incorrect procedures.

#### 3.4.2 Onboard Laboratory

In order to eliminate sample pass-outs, all equipment necessary to perform the required water analysis and medical procedures must be incorporated into an onboard laboratory. The procedures and equipment requirements for the Phase A test are defined in the Preliminary Test Plan CR-111999. requirements for the Phase B test will be determined after evaluation of the Phase A test results, but are expected to be similar.

The major equipment items required for the Phase A water chemical analysis are itemized in Table 9. The equipment items for microbiological analysis of water are discussed in Section 3.6. The conductivity bridge and pH meter listed on Table 9 were onboard during the 90-day test and the crew was required to determine the physical properties of the water samples. In addition, the microbiological analysis of the water was performed by the onboard crew. Therefore the only additional onboard requirements will be for chemical analysis of the water.

During the 90-day test the total organic carbon (TOC) determination was substituted for the chemical oxygen demand (COD) analysis as a working criteria for potability. The COD procedure is more complex, time consuming, and not suitable for onboard analysis. Therefore it is recommended that only the TOC determinations be conducted onboard during manned tests. The COD analysis will be performed prior to the start and immediately after the manned test to insure correlation of data. Analysis for metal ions cannot be accomplished onboard either, except for  $\text{Cr}^{+6}$ . These ions have never been detected after initial qualification of a recovery system since their normal source is improper materials. On the basis of this experience it is recommended that testing for metal ions need only be done before and after the test, at least during Phase A. Measurement of  $\text{Cr}^{+6}$  ions will be done onboard. The remaining chemical and physical analysis of water samples will be identical to the analysis performed during the 90-day test.

Elimination of sample pass-out in future manned tests poses particular problems in medically monitoring crew health. While the 90-day test revealed no medical problems ensuing from confinement in an artificial atmosphere, there can be no guarantee that future tests will always be so benign. The question then arises as to what biomedical samples are required and which of these must be analyzed onboard to provide real-time data. This question is best answered by considering two basic types of manned tests: those of short duration and those of long duration. Short-duration tests are arbitrarily put at 30 days or less and long-duration at greater than 30 days. This distinction is primarily based on observations of previous tests and missions by the Study Medical Director. On this basis, the requirements for biomedical sampling and analysis can be outlined.

Table 9  
ONBOARD LAB WATER ANALYSIS REQUIREMENTS

ITEM	FUNCTION	SPACE REQMT (Inches)	REMARKS
Total Organic Carbon Analyzer (TOC)	Measures organic & inorganic CO <sub>2</sub>	24 x 21-7/8 x 20	Requires: 1500 watts; breathing air supply; rear access for condenser water replacement. Operation: 1 hr heat-up of two pyrolysis ovens to 200°C & 850°C (calibration) and 10-15 min. analysis mode.
Strip Chart Recorder (TOC)	TOC hard data & calibration	under TOC	Pulls out, 12" - used for calibration of TOC-plug-in.
Infrared Analyzer	CO <sub>2</sub> analysis for TOC analyzer	9-2/3 x 11-2/3 x 28-1/2	Position next to TOC, plug-in
Conductivity Bridge	Conductivity	11-1/2 x 9 x 7	Counter placement, plug-in
pH Meter	pH	12 x 12 x 12	Counter placement, plug-in
Colorimeter	Measures color intensity Cr <sup>+6</sup> /NH <sub>3</sub>	10 x 14 x 8	Counter placement, plug-in
Power Supply	For colorimeter	8-1/2 x 13 x 9-1/2	
Turbidimeter	Measures turbidity	8 x 9-1/2 x 6	Counter placement, plug-in
Nessler Tube Rack	Cr <sup>+6</sup> /NH <sub>3</sub> measurement color comparison	17-1/2 x 5-1/2 x 18	Counter placement/no maint. required
Reagent Chemicals	Wet Chemical Analysis		May be stored in unused pass-through port

No real-time biomedical sample data are considered necessary in tests of 30 days or less such as the Phase A test. On-board samples should be collected, however, preserved and analyzed post-test for comparison with matched pre and post-test samples. These analyses provide objective confirmation of other observations in regard to crew health and provide retrospective data on test effects other than those overtly pathologic. If follow-on long tests are planned, some on-board analysis may be carried out to establish on-board laboratory feasibility even though not required for the operating protocol of a short duration test.

In addition to blood and urine samples for retrospective study, certain on-board procedures are required in order to monitor crew health for the Phase B test. These procedures will be selected on the basis of relative medical value and on the basis of practicality. The latter includes crew skill, complexity of hardware, cost and safety considerations.

#### 3.4.3 Communications System

Major differences in the communications system for the extended test beyond that provided during the 90-day test include improving the acceptability of the communications headsets in the equipment quarters, and improving the acceptability of audio entertainment facilities by enhancing the fidelity of output devices onboard the chamber. Two communications headsets for use in the equipment quarters will be outfitted with press-to-talk feature and will also include binaural headsets. This will be accomplished in order to eliminate expressed annoyances by crew members to the feedback characteristics of the existing monaural headsets. High fidelity stereophonic entertainment headsets will also be provided for each crew member for use in the crew quarters.

#### 3.4.4 Emergency Equipment and Procedures

The planned extended manned tests differ from the 90-day test in terms of requirements for emergency equipment and procedure only in that the future tests will be conducted at a cabin pressure slightly above atmospheric (775 torr or  $103.3 \text{ kN/m}^2$ ) whereas the 90-day test pressure was nominally  $68.9 \text{ kN/m}^2$  (517 torr). The new atmosphere is, therefore, 20% oxygen while that previously

tested was 30% oxygen. This change in oxygen content does result in some reduction in flammability of materials. However, other than a change of some fabrics such as crew clothing to Nomex from Durette, no significant relaxation in material control or in emergency equipment and procedures is recommended. Those procedures used during the 90-day test did not impose any operating complications or cost effects that can be reduced by reasonable changes.

One result of the increased chamber pressure is to reduce the time required to equalize cabin pressure to external ambient and thereby to gain access to the chamber or to egress the crew in the event of a need for an emergency abort. Minor changes in abort procedures have been made in the Preliminary Test Plan to take advantage of this time reduction.

The provision of privacy in the sleep area, acoustic isolation of the bunks, and additional personal storage space has resulted in a decision to remove the inner airlock door. The airlock will, therefore, not be available for crew shelter during a possible introduction of smoke into the atmosphere, and procedures need to be adopted to assure the maintenance of clear access through the airlock, so that storage in this location does not block an emergency egress.

#### 3.4.5 Supporting Equipment and Procedures

The requirement for analysis or retention of all biomedical, microbiological and potable water samples onboard during the extended manned test, in order to eliminate sample pass-out operations, will reduce the required level of effort which was applied to these tasks by supporting staff as compared with the 90-day test period. A corresponding increase in the post-test analysis of samples will, however, occur due to the accumulation that will occur in storage within the chamber. This difference will mainly be reflected in lower peak man-loading of the program during the test, and more extended period for post-test analysis. The details of onboard laboratory facilities for storage or analysis of these samples are described elsewhere in this report.

### 3.4.6 Simulator Design Layouts

Some changes in the interior layout of the simulator are planned as a result of recommendations from the 90-day test and requirements for integration of new advanced subsystems. Figure 17 shows the planned layout for the Phase A test. The following changes have been made:

A zero-g shower is installed in the crew hygiene area, with necessary relocation of the sink, and the multifiltration columns and water storage tanks of the wash water recovery unit. A separate enclosure is provided in the equipment room for the commode since there is not room for its installation in the old crew hygiene compartment.

The crew life support monitor has been relocated to the living quarters and located at the head of the dining/recreation table to facilitate monitoring. The area previously occupied by this unit can be used for the static-vapor feed water electrolysis unit if this unit is used for the Phase A test.

Two bunks have been removed and the counter/storage space for the onboard laboratory has been extended into the area previously occupied by them. This was indicated by the requirement for additional analytical equipment required to eliminate sample pass-outs and by the crowded conditions that occurred on all available counter space during the 90-day test when the required equipment was installed.

The remaining two bunks have been enclosed by a sound and light attenuating wall. To accomplish this installation, the inner airlock door has been removed. This is practical since the airlock is no longer required for crew ingress due to the operation of the chamber at approximately atmospheric pressure.

In evaluating proposed changes for the Phase B test, the possibility of using a six-man crew has been considered. This was done since the planning for the Modular Space Station presently envisions a six-man crew and the

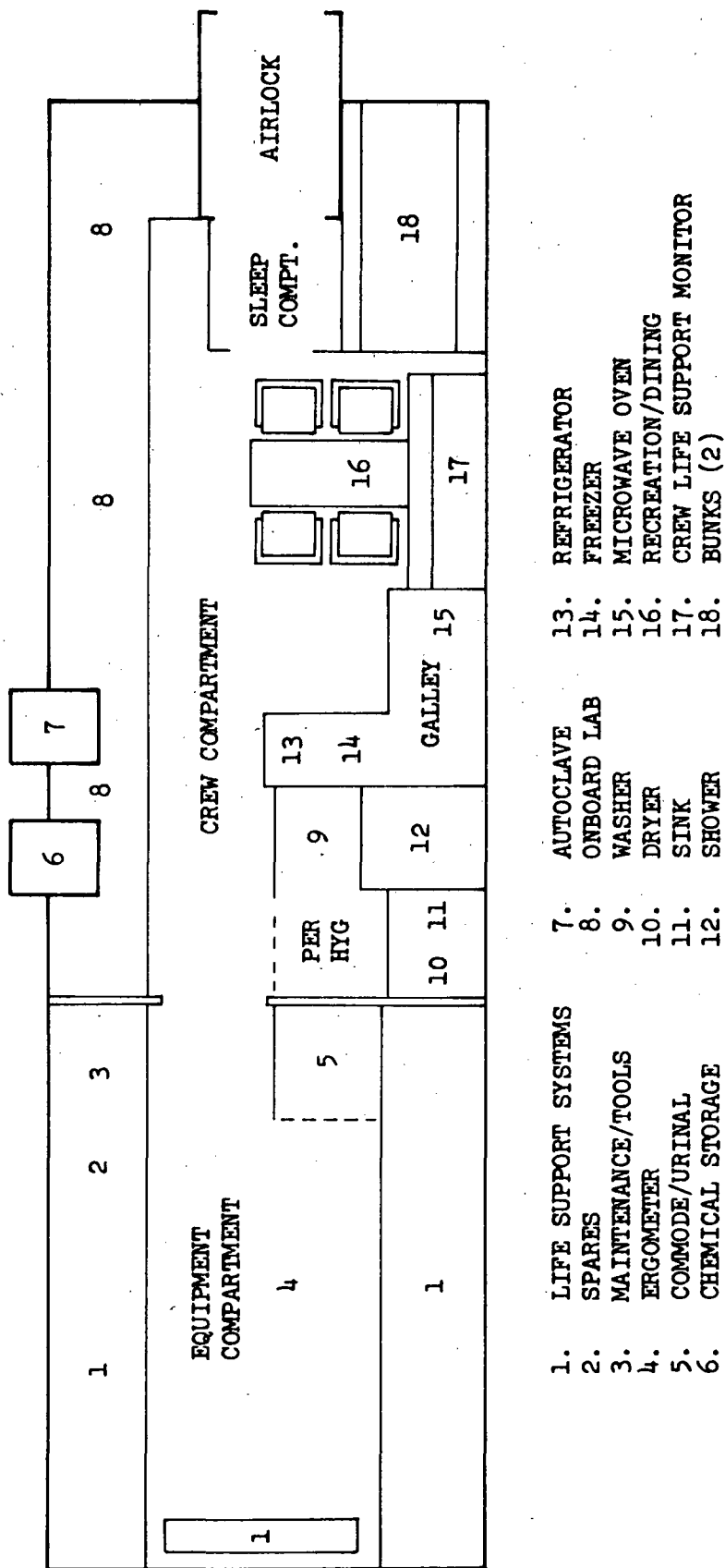


FIGURE 17. RECOMMENDED SIMULATOR CONFIGURATION - PHASE A

Space Station Prototype (SSP) system design is for six men. Preliminary layouts of a modified Phase A simulator to accommodate a six-man crew indicated that such crowded conditions would result that adequate room for advanced subsystem installation would not be available. A substantial reduction in fidelity of the simulation would also result.

It was, therefore, determined that the use of a six-man crew would require the construction of an enlarged test chamber. Several layouts were made of possible configurations. The most promising of these is shown in Figure 18. This includes the addition of a habitability module to the present simulator chamber and using the latter for life support equipment and onboard laboratory.

This configuration is intended to resemble the modular space station design to some extent, although the limitations imposed by 1-gravity design and by the existing chamber have necessitated some compromises. The layout features improved accommodations for each crewman, with two bunks, a desk and a chair in each compartment, and increased personal storage space. Personal hygiene facilities feature a separate shower room large enough to enable dressing room space and a laundry room.

The proposed habitability addition would be approximately 4.1 meters (13-1/2 ft) diameter and 12.2 meters (40 ft) long, which approximates the size of a module of the proposed Space Station. It is not necessary to provide a double-wall construction, as the 90-Day Test Chamber, since it would always be operated above atmospheric pressure. An emergency exit is required in the added chamber, and is shown in the layout. Not shown is the possibility of providing a relatively high floor with space underneath for water storage tanks and spare parts storage. This is consistent with SSP design planning.

Evaluation of the six-man crew proposal indicates that the main advantage in comparison with a four-man crew is the improved simulation of the psycho-social situation on the proposed space station. More life support equipment is to be available with a four-man capability than with a six-man capability. Allowance



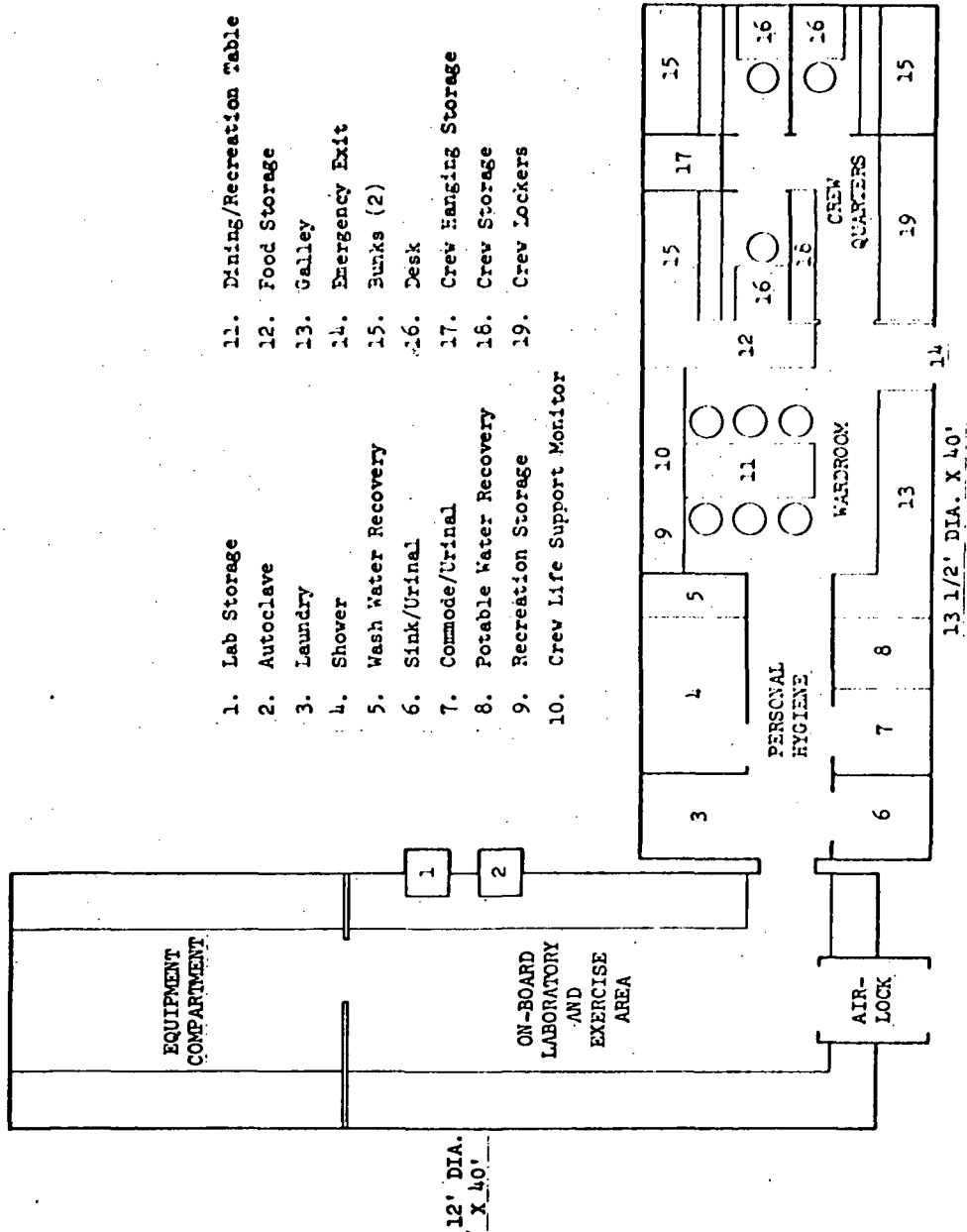


FIGURE 18. RECOMMENDED 6-MAN SIMULATOR

can be made for equipment having excess capacity but it is usually not possible to increase the capacity of a small system, and restrictions in selection of advanced subsystems would result.

In view of these considerations, the planning for the Phase B test has been done

### 3.5 AEROSPACE MEDICAL SUPPORT REQUIREMENTS

In any test situation where humans are confined in an artificial environment using developmental equipment, certain medical requirements must be met. These include emergency medical care capability and medical monitoring of crew health. The latter may include full-time instrumentation, part-time instrumentation, body fluid sampling, interviews and various tests. In this confined situation, microbiology assumes additional importance not only in regard to crew health but also in regard to hardware evaluation and baselines for future tests and missions. Finally, the test situation provides a unique opportunity for evaluation of man in operational one-g confinement. There are a number of candidate studies taking advantage of this opportunity on a non-interference basis which may be outlined.

#### 3.5.1 Medical Management

##### Emergency Medical Care

Professional medical support must be immediately available at all times during the test. A properly equipped medical station with a capability for cardio-pulmonary resuscitation and emergency burn care must be adjacent to the test facility. Arrangements for ambulance service and hospital care must be made prior to the test.

##### Test Medical Procedures

Full-time physiologic monitoring is not required for long-duration, low stress tests. Certain procedures, however, are important in the evaluation of crew health status. The 90-day manned test included complete basal signs, weekly

electrocardiogram, and weekly pulmonary spirometry in addition to personal medical interviews daily and body fluid sampling. In reviewing that test, some procedures contributed minimally to test data. These include the daily heart rates and blood pressure and the weekly electrocardiogram; these can be deleted in future tests as routine scheduled procedures. Body fluid (blood and urine) samples were generally valuable and this program should be enhanced in frequency, scope, and in better baseline data (see Section 3.5.2).

Recommended baseline medical test procedures and sampling are presented in detail in the Preliminary Test Plan NASA CR-111999 (Section 9) and outlined here. Some on-board sample processing is included in order to develop that capability for future long-duration tests.

#### Daily Medical Procedures

1. Basal body temperature and weight.
2. Private medical interview.
3. Urine sample for post-test analysis.

#### Weekly Procedures

1. Pulmonary spirometry
2. Blood samples for post-test analysis.
3. Hematology (on board)
4. Nasopharyngeal microflora (on board)

A preliminary model has been developed for reduction of the data from the samples by computer. A major problem in the 90-day test centered on data reduction. The experimental design and computer analysis under consideration should solve that problem in future tests. This design is detailed in Appendix A, which also notes the use of baseline data and controls. The sampling frequency is exemplary only and the frequency actually decided for the test can be applied to the design.

### 3.5.2 Pre and Post-Test Biomedical Baseline Data

One of the major problem areas in the 90-day manned test involved inadequate baseline data. Appendix A amply demonstrates the usefulness of such data and provisions must be made for obtaining it in future tests. These baselines must also include diurnal samples if a split-shift crew schedule is planned in order to rule out normal circadian rhythm influences in analytical results. The type and frequency of sampling and analyses to be run are detailed in Section 9 of the Preliminary Test Plan NASA CR-111999.

### 3.5.3 Potential Medical Studies

A preliminary list of candidates for medical auxiliary studies has been prepared. The studies are separated into two groups: (a) follow-on studies to the 90-day test and (b) new candidate studies and equipment tests. These studies are not considered to be necessary in accomplishing the major test objectives and are, therefore, not presently included in the Preliminary Test Plan NASA CR-111999. They can be included in the program, however, and are suggested since they offer the opportunity to obtain very valuable data on medical effects of confinement at a moderate increase in program costs. The proposed follow-on studies include:

#### Time Course of Circadian Recycling

The 90-day test suggested that recycling diurnal biochemical rhythms require significantly longer (Ca. 35 days) than previously thought. The data, however, were incomplete since this observation was unexpected and there was no protocol specifically designed to study it. The protocol for a more detailed study includes:

- a. Better pretest and post-test baselines for diurnal variations in blood chemistry and hematology.
- b. More precise measurement of body temperature.
- c. More frequent sampling for urine chemistry pretest, during the test and post-test.
- d. A more detailed and, hopefully, more sensitive psychomotor evaluation.
- e. Sleep evaluation during the entire adjustment period.

## Low CO<sub>2</sub> Effects

90-day test data suggested that exposure to CO<sub>2</sub> levels mostly less than 5.5 mmHg produced no discernible effects during the first 45-50 days. In the last half of the test, however, changes were seen in blood calcium levels. If the Ca changes were caused by the CO<sub>2</sub> exposure, they were produced either by the additional exposure or by exposure to higher excursions superimposed on the continuing low level. The 90-day data are inconclusive in all of these points, however, since it now appears that (1) the blood sample methods for acid-base and blood gas analysis were of questionable validity (personal communication, C. J. Lambertsen, M.D., University of Pennsylvania), (2) samples for Ca were too few for good statistical analysis - the Ca observation was unexpected - and, (3) pretest baselines in blood and urine chemistry were inadequate. It is, therefore, proposed to restudy the low level CO<sub>2</sub> problem in order to define in greater detail the biochemical effects. The protocol includes the following candidate procedures:

- a. Better pretest urine and blood chemistry
- b. Evaluation of individual crew members' respiratory sensitivity to CO<sub>2</sub>.
- c. Test samples, properly processed, for acid-base and blood gas analysis. These samples should be analyzed on board but serum preservation techniques will be evaluated if on-board analysis is not feasible.
- d. Daily urine samples preserved for hydrogen ion and Ca excretion and hydroxyproline.
- e. Daily blood samples preserved for Ca analysis.
- f. Calcium kinetics study using isotopic calcium.
- g. Controlled Ca-Phosphorus and Vitamin D input.
- h. Fecal analysis for Ca excretion treating the crew en masse since individual samples are not feasible for these tests.

### Whole Body Exercise Evaluation

The 90-day test results suggested that whole body exercise is required for maintenance of lean body mass in confinement. This hypothesis will be tested using a differential controlled exercise program.

- a. A whole body exercise program will be devised for half the crew - the others will use the ergometer alone.
- b. Better pretest baseline will be established.
- c. Ad lib exercise will not be allowed.
- d. Pretest and post-test lean body mass determinations will be improved.

### Crew and Individual Water Balance

Data from the 90-day test are excellent except for accurate input figures for metabolic water. This deficiency is a consequence of inadequate information on food composition. The discrepancy between engineering data and medical data on evaporative water loss falls within the range of usual metabolic water production. Since evaporative loss, hence urine volume, was dependent on dry bulb temperature, even in the absence of extremes of DBT, (unpublished observation) these data should be refined. The following protocol will be established.

- a. Pretest water balance will be evaluated.
- b. Food composition (CHO, protein, fat) will be determined - including snack items.
- c. Water input, output will be measured as in the 90-day test.
- d. Fecal water will be measured for the crew en masse in three separate fecal collections.

### Nasopharyngeal Microflora Exchanges

One CM in the 90-day test carried a heavy Neisseria meningitidis infestation. Transfer of this organism to other CM was insignificant in spite of the confinement--this was unexpected in view of general control procedures in epidemics caused by this organism. Host resistance may have played a role but it is possible that stringent measures in respect to crowding are not really required. The same phenomenon occurred with the lack of transfer of a -hemolytic streptococcal infestation. It is proposed to evaluate further

this observation using information from the baseline medical microbiological program. In addition, pretest nasopharyngeal microflora baselines will be established.

#### Potable Water Evaluation

90-day test data are incomplete for viral contamination of potable water and for measurement of detailed biological byproduct contamination. A program is proposed for a complete study in this area. Samples preserved onboard at -70°C will be required.

#### Biochemical Correlates of Low Level Stress

90-day test data suggested that urinary Na/K ratios may be useful in following low-level psychological stress. The data, however, were too infrequent to be conclusive and pretest urine baseline data were lacking. These deficiencies will be corrected in future tests.

New auxiliary study candidates include:

#### Diurnal Variation in Body Water Balance

This study will make use of baseline individual water input-output data and will add whole body impedance measurements (developmental).

#### Tracer/Marker Organisms for Environmental Monitoring

This study will make use of known organisms in environmental monitoring.

#### Microbial Load Monitor (MLM) Evaluation

The MDAC-East MLM will be evaluated in the 4-week test for baseline inclusion in the 9-week test.

#### Automatic Blood Collection and Preservation Device (ABCP)

The ABCP under development by MDAC-East will be evaluated in the 4-week test for baseline inclusion in the 9-week test.

#### Lymphocyte Specific Gravity Distribution (LSGD)

The developmental LSGD test will be evaluated for use as baseline in future programs.

### 3.6 MICROBIOLOGICAL STUDIES

A microbiological program is essential to monitoring human, environmental, and system parameters affecting the health and safety of the crew during extended manned tests of advanced regenerative life support systems. The 90-day test plan involved both onboard and outside laboratory analyses of microbiological specimens. Major objectives were to certify potable water safety and to continuously survey microflora indigenous to the manned chamber. Results showed no changes of great significance to crew health or safety but pointed out many areas for investigation which can provide improved microbiological data during future tests. Some of these should be incorporated in the baseline program to provide improved microbiological protection, and others will result in valuable developmental data and, although not necessary to the successful operation of the test, will be helpful in designing methods and equipment for future space laboratory applications.

The following are recommended for inclusion in the next manned test to provide additional insurance against microbiological problems:

1. More thorough and extensive pretest baseline data on the test crew.
2. More extensive control of contamination of the facility during pretest preparation and pretest monitoring of microbial contaminant levels.
3. More effective methods for microbial control in water recovery and distribution systems.
4. Use of improved germicidal techniques for treating stored wastes.
5. Development of onboard microbiological laboratory capability.

The Preliminary Test Plan NASA CR-111999 defines methods and equipment necessary for accomplishing the above objectives.

Areas in which useful developmental data may be obtained are as follows:

1. More extensive post-test data on test crew and equipment.
2. Improved methods for tracking cross-transmission of common organisms between crewmen.
3. Development of more rapid techniques for more frequently monitoring microbial loads in water and atmosphere.



4. Development of more reliable methods for recovery of fastidious microorganisms.
5. More quantitative bioassays of contamination levels on surfaces and within components.

Since these areas are not considered essential to the performance of extended manned testing, they have not been incorporated into the Preliminary Test Plan NASA CR-111999 but may be subsequently added as Special Studies.

For future manned tests, new or improved techniques and approaches, based on previous manned test experience, will be incorporated into experimental design. An onboard laboratory capability will provide 1) continuous surveillance of microbial activity during the test and 2) appropriate preservation of samples for more extensive study post-test. Because all pass-ins and pass-outs will be eliminated to maintain mission realism, sufficient stores of onboard supplies will be necessary. Contamination of the closed microecology will be precluded by positive pressurization in the interior. Man's capability for in-flight monitoring will be evaluated during the proposed Phase A test. The rationale used in definition of the microbiology program for this test is presented below.

#### 3.6.1 Crew Monitoring

Evaluation of the microbiological profiles of crew members is necessary in order to 1) determine whether pathogenic organisms are present, 2) detect gross quantitative and qualitative shifts in indigenous microflora which are potentially harmful, 3) study cross-infections during extended simulation studies in closed environmental systems, 4) improve techniques for epidemiological investigations in closed microecological systems such as a space station, and 5) determine types of human microflora which might cause interference with components of the life support system under test.

No changes were seen in the microecology of significance to crew health or safety during previous manned tests (References 1 and 4). Results generally support the growing body of evidence that ground-based closed tests do not markedly affect the

microecological balance or host sensitivity to microorganisms. However, these tests showed that baseline data on the indigenous flora of crew candidates were inadequate in terms of sample frequency and duration. Pretest samples for the 60-day test were taken on -6 day and just prior to crew ingress on day 1; for the 90-day test, on -4 day only. After the 90-day test was in progress, it was discovered that one of the crew members was a carrier of Neisseria meningitidis. If known before the test, this finding would have probably disqualified him. Growth scores for his throat swabs increased to the maximum number from the third week on through the end of the test. N. meningitidis was recovered from another crewman on test days 25 and 32; but since serotyping was not performed, it is unknown whether there was a transfer. Fortunately, no clinical symptoms attributable to this organism developed.

Both tests showed that more reliable marker systems for following transmission of common pathogenic organisms are desirable. One of the most significant findings of the 60-day test was that there was no evidence that Staphylococcus aureus was spread from the two crew members who were nasopharyngeal carriers to the other two men who entered the simulator free of this organism. During the 90-day test, no conclusive data were obtainable on possible transmission from two carriers, one of S. aureus and the other of Neisseria meningitidis as noted above.

During the 60- and 90-day tests, microbiological samples from the crew members were taken weekly and immediately passed out to an outside laboratory via passthrough airlocks. During the latter test, materials were passed out only by means of an autoclave-airlock which insured a microbiologically closed system. For future tests, development of an onboard microbiological laboratory is required in order to meet the constraints for no pass-out and provide for processing of samples, preliminary identification, and storage until post-test analysis.

This laboratory will provide a mission-realistic capability for monitoring microbial changes in the microecology which may be detrimental to the health and safety of the crew. In addition, it will determine which types

of microorganisms are involved in the event of illness or health hazard and perform antibiotic sensitivity tests as an aid in treatment measures. Samples, not only of crew microflora but from their environment (water, surfaces, hardware subsystem components, and atmosphere), will be taken during the test for comparison with pretest and post-test data. Routine, emergency, and contingency samples will be appropriately preserved for post-test analyses. Also special research studies could be conducted to evaluate space-prototype monitoring devices for microbial load, water potability and cross-transmission studies.

Post-test data on the indigenous flora of crew members from previous tests have been too sparse for significant interpretations, viz., for the 60-day test, samples were taken immediately after crew egress, at +8 hours, and +40 days; for the 90-day test, at +18 days only. More detailed data, at more frequent intervals, are desirable to determine post-test changes.

In reviewing the results of previous tests, the following program is recommended for future extended manned tests:

#### 3.6.1.1 Pretest Screening

It is recommended that more extensive data be obtained in screening crew candidates for carrier states of pathogenic microbial types and indigenous microbial flora be included as criteria for final crew selection.

The following procedures should be followed in accomplishing this objective. These procedures are outlined in the Microbiology section of the Preliminary Test Plan CR-111999 .

#### Skin Tests

Standard clinical screen tests for 1) tuberculosis, 2) histoplasmosis, 3) blastomycosis, 4) coccidioidomycosis, and 5) brucellosis will be performed as part of the secondary screening procedure for potential candidates.

### Nasopharyngeal Samples

Samples of nasal and oropharyngeal microflora will be taken from all crew candidates prior to final crew selection. The prime and backup crews will be tested semi-weekly starting on -28 test day for the following bacterial pathogens:

- 1) Staphylococcus aureus - coagulase positive
- 2) Diplococcus pneumoniae
- 3) Neisseria meningitidis
- 4) Hemophilus influenzae
- 5) streptococcus - beta-hemolytic

Other microflora of possible interest are:

- 1) streptococcus - gamma
- 2) lactobacillus
- 3) Corynebacterium diphtheriae
- 4) veillonella and other anaerobes
- 5) mycoplasma
- 6) Candida albicans and other pathogenic fungi

### Stool Samples

Stool cultures will be made to insure against gastrointestinal carriage of enteric bacterial pathogens, e.g., species of Salmonella and Shigella.

### Urine Samples

Mid-stream urine samples will be taken from each crew candidate in an aseptic manner. Aerobic and anaerobic quantitation of microflora will be performed using Blood, Staphylococcus-110, MacConkey and Rogosa agar media.

### Throat-Mouth Gargle

Each crew member will gargle in a prescribed manner with a prescribed volume of sterile phosphate buffer. Aerobic and anaerobic quantitation will be made on Blood, Staphylococcus-110, Mitis Salivarius, 3-Antibiotic, and Rogosa agar media.

### Dermal Samples

Calcium alginate swabs will be used to sample the scalp, external auditory canals, axillae, umbilicus, inguinal region, toe webs, and hands. Aerobic and anaerobic quantitation will include inoculation of Blood, Staphylococcus-110, and various mycological media.

### Viral Samples

Viral studies (TBD) will be performed on the following samples:

- 1) Nasal and oropharyngeal swabs
- 2) Throat washings
- 3) Serum
- 4) Feces

As a result of obtaining these data, it will be possible to ensure that crew members will not be carriers of highly pathogenic microorganisms and that statistically significant baseline data will be obtained on pretest microbial profiles.

#### 3.6.1.2 Crew Training

Candidate crewmen will include individuals with formal training in biological sciences, especially microbiology. As part of the medical training of crew members, one or more of the crew will be trained to be proficient in collecting valid samples and performing onboard lab procedures/analyses. This training will include techniques for aseptic collection and handling of specimens, inoculation and incubation of culture media, quantitative and qualitative analyses, and maintenance and preservation of specimens and cultures. Proficiency of the crewmen responsible for the microbial program will be demonstrated and practiced during repeated practice sessions.

#### 3.6.1.3 Onboard Laboratory Monitoring of Crew/Environmental Microbiology

The onboard laboratory will be designed to perform procedures/tests presented in Table 10. (Note: The list is tentative and includes multiple approaches under consideration at this time (References 5-9)).

TABLE 10

## ONBOARD MICROBIOLOGY LABORATORY CAPABILITY

<u>PROCEDURE</u>	<u>METHODS/REMARKS</u>
1) Sample collection and handling	<p>Crew</p> <p>Nasopharyngeal swabs, saliva, or wire loop samples</p> <p>Potable and wash water</p> <p>Whirl-Pak bags</p> <p>GFE-Apollo Water Sampling Device (AWSD)</p> <p>Millipore field monitor</p> <p>Millipore sterile tank sampling port</p> <p>Surfaces</p> <p>Swabs or swab-rinse</p> <p>Soluble gel</p> <p>Rodac plates</p> <p>Template and swab</p> <p>Fallout coupons</p> <p>Atmosphere</p> <p>Microbiological</p> <p>Reyniers, Casella, Anderson samplers</p> <p>All glass impinger - Millipore</p> <p>Soluble gel</p> <p>Settling plates - for fallout contamination</p> <p>Particulate aerosol-monitoring</p>
2) Preparation of culture media	Pour plate techniques and non-routine investigations
3) Dilutions	Microtitration techniques
4) Inoculation of culture media	<p>Crew</p> <p>Nasopharyngeal swabs will be streaked onto plates of appropriate culture media for semiquantitation and detection of medically significant bacteria:</p> <p><u>Staphylococcus aureus</u> - coagulase positive</p> <p><u>Diplococcus pneumoniae</u></p> <p><u>Neisseria meningitidis</u></p> <p><u>Hemophilus influenzae</u></p> <p><u>Streptococcus</u> - beta hemolytic</p>

TABLE 10

## ONBOARD MICROBIOLOGY LABORATORY CAPABILITY (CONTD.)

<u>PROCEDURE</u>	<u>METHODS/REMARKS</u>
4) Inoculation of culture media (cont.)	<p>Potable and Wash Water</p> <p>To meet NASA standard for microbiological quality of drinking water, the following determinations will be made:</p> <ul style="list-style-type: none"> <li>Total bacterial count</li> <li>Coliform count</li> <li>Yeast and mold count</li> <li>Total anaerobic count</li> <li>Others to be determined (TBD), e.g., viruses</li> </ul> <p>Surfaces</p> <ul style="list-style-type: none"> <li>Total aerobic cfu* per square foot or other area</li> <li>Total cfu* per Rodac plate</li> <li>Total bacteria vs total fungal counts</li> <li>Total aerobes vs total anaerobes</li> <li>Total vegetative vs spore-formers</li> </ul> <p>Atmosphere</p> <ul style="list-style-type: none"> <li>Total cfu per cubic foot vs time</li> <li>Total cfu per cubic foot at airflow velocity of (TBD) ft/min with total (TBD) cubic feet sampled</li> </ul>
5) Differential Tests for Nasopharyngeal isolates	<ul style="list-style-type: none"> <li>Optichin sensitivity</li> <li>Bacitran sensitivity</li> <li>Coagulase - slide test only</li> <li>"N" disc</li> <li>Fermentation broths - glucose, mannitol, sucrose</li> <li>Slide agglutination test</li> <li>Subculture media</li> <li>Catalase test</li> <li>Quellung test (pneumococcus &amp; hemophilus)</li> <li>Capsular swelling (hemophilus)</li> <li>X &amp; V factor strips (hemophilus)</li> </ul>

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\* cfu = colony-forming unit

TABLE 10

## ONBOARD MICROBIOLOGY LABORATORY CAPABILITY (CONT.)

PROCEDURE

METHODS/REMARKS

6) Incubation of Culture Media

Temp.

Naso-

pharyngeal

Atmosphere

°C

Water

Surf.

Atmos.

Sample

Aerobic

30

X

X

X

Aerobic

32

X

X

Aerobic

35

X

Aerobic

37

X

5-10% CO<sub>2</sub>

37

X

Anaerobic

32

X

X

Anaerobic

35

X

Anaerobic

37

X

10% CO<sub>2</sub> +

37

X

90% N<sub>2</sub>

7) Morphological Study of Colonies

Stereomicroscope

Hand lens

Colony counter

8) Microscopic Examination of Unstained and Stained Preparations

Microscope with low, high-dry, oil immersion objectives

Gram stain

Spore stains (bacteria)

Lactophenol Blue (fungi)

Methylene Blue (diphtheroids)

Wet Mount

9) Antibiotic Sensitivity Testing

Nasopharyngeal flora only

Disk Dispenser and Cartridges

10) Preservation of Isolates

Nasopharyngeal flora

Staphylococcus - transfer to agar slants →4°C

Diplococcus - Transfer to Brain Heart Infusion Broth and neopeptone + rabbit blood →4°C or lyophilize

Weisseria - transfer to broth + 10% glycerol or 10% serum & →below -40°C



TABLE 10

ONBOARD MICROBIOLOGY LABORATORY CAPABILITY (CONT.)

<u>PROCEDURE</u>	<u>METHODS/REMARKS</u>
10) Preservation of Isolates	<p>Hemophilus - semifluid agar better than slants or broth media; cultures should be transferred each week or more often and kept in the incubator (they die rapidly under refrigeration). If cultures are to be used for experimental work, it is best to freeze-dry them immediately after isolation.</p> <p>Streptococcus - stock cultures → blood broth without dextrose → 4°C.</p> <p>Water</p> <p>Save all contaminants for post-test analysis--after picking to agar slants from isolation plates, incubate the same as before; then refrigerate slants or lyophilize therefrom.</p> <p>Surfaces</p> <p>Same as for water, or else hold primary isolation plates @ 4°C until post-test analysis.</p> <p>Atmosphere</p> <p>Same as for water, or else hold primary isolation plates @ 4°C until post-analysis.</p> <p>Note: Other preservation methods: 1) inoculation of Stuart's transport medium, 2) covering with sterile mineral oil.</p>
11) Onboard Lab Safety Provisions	<p>Chemical disinfectant used on inoculating bench (hood) surfaces after each use, e.g., Zephiran 1:750 or Wescodyne</p> <p>Hood with various safety features: Germicidal irradiation (UV lamp) when not in use Air-circulation - free area for staining and inoculating Smooth interior finish (fiberglas) hood insures easy cleaning and no contamination accumulation</p>

TABLE 10

## ONBOARD MICROBIOLOGY LABORATORY CAPABILITY (CONT.)

<u>PROCEDURE</u>	<u>METHODS/REMARKS</u>
11) Onboard Lab Safety Provisions (cont.)	UV proof sash and bi-fold doors "Out-of-the-way" location of hood No eating or drinking near hood  Autoclave available for emergency media preparation and destruction of cultures and contaminated materials. All materials to be discarded held in covered containers with disinfectant.  Culture plates, tubes, pipettes, etc., will be made of non-breakable material--glass will be avoided.  Safe storage of hazardous chemicals and wastes  Heat-fix all smears on a slide warmer for at least 2 hours at 65°C  Frequent number of air changes--TBD
12) Special Studies	These are discussed separately in Section 3.6.4.

#### 3.6.1.4 Post-Test Samples and Analysis

Upon completion of the closed test, the following sampling procedures and schedules will be followed in order to provide baseline microbial data:

- 1) Nasopharyngeal samples - The crew will be tested semi-weekly, starting immediately after egress from the chamber and continuing through +28 days for the same bacterial pathogens as for pretest samples.
- 2) Stool samples - Same as for pretest.
- 3) Urine samples - Same as for pretest.
- 4) Throat mouth gargle - Same as for pretest.
- 5) Dermal samples - Same as for pretest.
- 6) Viral samples - Same as for pretest.

#### 3.6.2 Environmental Monitoring and Contamination Control Requirements

The imposition of more extensive clean room conditions on the chamber interior during pretest preparation is recommended for several reasons. Reliable baseline data on initial types and levels of organisms associated with the chamber atmosphere and surfaces prior to crew ingress will be obtained. Low contamination levels, especially of environmental fungal types which were isolated during the 90-day test, will promote crew health and safety and prevent life support system malfunction/deterioration during the test.

These objectives require a carefully planned and executed program of particulate contamination control (Reference 10). Because microorganisms are also particles, the control of particles also tends to control microorganisms. although the exact nature and extent is not fully defined. Particulate contamination mostly concerns particles greater than  $0.3 - 0.5\mu$  in size, while microbial contamination involves particles approaching  $0.1\mu$ . Fortunately, most microorganisms occur in large clumps rather than singly so that their control is greatly facilitated by mechanical methods. However, these facts must be considered whenever numerical levels of both types of contamination are compared: 1) the number of non-viable particles remains constant during hardware storage, while that of viable particles

(microorganisms) may change depending on environmental conditions;  
2) processes which are performed free from human contact and unfiltered air may not increase the number of viable particles but may increase levels of non-viable particles by sloughing or flaking of material.

Major sources of contamination are personnel, processes, materials, and fallout from the atmosphere. Microbiological monitoring of clean room facilities has shown that most types of contaminants present in the air are those indigenous to humans and their levels depend on the degree of activity of the occupants in the facilities.

In regard to surface contamination, no analyses were performed during the 60-day test, but the 90-day test included weekly monitoring of two areas in the food management and hygiene compartments during the test and an extensive post-test sampling program of surfaces and subsystem components. Samples during the test yielded Staphylococcus epidermidis and other aerobic microflora indigenous to the human skin. Even though quantitative methods were gross, a buildup was noted in the hygiene area and underscored the need for scheduled cleanup practices. Post-test surface and subsystem component sampling confirmed that the crew members were a major source of bacterial contaminants. Fungal isolates included yeasts and species of Aspergillus, Erodium, Penicillium, Pullularia, and Rhodotorula. The lack of baseline data and accurate bioassay techniques were major deterrents to valid conclusions about buildup.

#### 3.6.2.1 Pretest Contamination Control for the Test Chamber

The NASA-MSC contamination control program (Ref. 11) is a guide to requirements necessary to assure required cleanliness of space systems and elements thereof. Provisions for (1) controlled work areas (maintenance, special garments, operations, contamination generation control, (2) clean room conditions (classes, design, airborne contamination, ranges of temperature and relative humidity, positive pressure), (3) process requirements (special cleaning processes), and (4) sampling and certification of clean rooms and personnel are well documented. MDAC has instituted a contamination control program for the Orbital Workshop (OWS) which provides a ready, in-house

capability which can be studied and adapted to needs for a manned test in the test chamber. NASA methods for the microbiological examination of spacecraft hardware have been standardized. These involve assays for mesophilic aerobes, anaerobes, vegetative cells and spore formers.

The lowest level of cleanliness (Federal Standard 209a, Class 100,000) will be established for the interior of the chamber at least (TBD) days before crew ingress. Procedures will be based on the NASA-MSD contamination control program and requirements implemented during OWS installation, test and transport procedures. Control methods for surface and atmosphere contaminants, such as the use of non-ionic detergents, 70% isopropyl alcohol wipes, laminar air flow, positive pressure, and clean room garments (smocks, caps, booties, gloves) will be applied. No additional contamination reducing methods, viz., germicidal application, UV irradiation, or gas decontamination, will be applied.

Microbial air and surface monitoring tests will be run during OWS buildup and checkout to obtain baseline data concerning local microbial types and levels that will enhance baseline data obtained later. Atmospheric monitoring will be performed using samplers, settling plates, and fallout coupons while surface monitoring will involve swab, soluble gel or Rodac techniques. Particular attention will be given to recovery of fungal types using appropriate media and of aerobic and anaerobic bacteria (vegetative and sporulated). Virus detection will not be imposed. Particulate analysis will be concurrently performed to provide complementary data on the contamination picture.

#### 3.6.2.2 Atmospheric Monitoring

During the performance of an extended closed chamber test, microbial contaminants in the simulator atmosphere must be monitored for changes in levels and types affecting crew health and safety and performance of the atmosphere control subsystem.

Even though there were no unusually stringent contamination control measure prior to both 60- and 90-day tests, airborne microbial levels were quite low, in fact, comparable to those in laminar airflow rooms used to provide low-pathogen environments for patients with high risks of infection.

During the 60-day test, growth on air sampling plates showed that the initial population became simplified during the first two days of the test and remained constant for the remainder of the test (about 1 viable particle/ft<sup>3</sup>). After crew egress, a rapid reversion to the outside ambient population was observed.

Data points for microbial levels during the 90-day test were sparse (2 Reyniers sampler tests on -1 day, 2 tests every 2 weeks during the test, and 2 tests on +4 day) and not correlated with mission profile periods of high aerosolization. Furthermore, cultural conditions were not optimal for recovery of many microbial types. Bacterial counts ranged from 0.02 - 3.0/ft<sup>3</sup> and fungal-type counts from 0 - 0.23/ft<sup>3</sup>. Bacterial contaminants, mostly from human occupants pretest or the crew included Staphylococcus epidermidis, S. aureus, and species of Micrococcus, Aerococcus, Sarcina, Bacillus, Corynebacterium, Neisseria, Alcaligenes, Enterobacter, and Proteus. Staphylococci and bacilli were the predominant isolates. Preliminary identification results for fungal isolates show that yeasts and species of Aspergillus, Penicillium, Hormodendrum, and Rhodotorula were present. Both microbial and particulate analyses showed that a uniform distribution of airborne contaminants was established probably as early as the third week.

As part of the pretest contamination control program, samples should be taken of the OWS interior as well as the simulator interior. Monitoring will be accomplished via air samplers (Reyniers, Anderson, Casella slit or NASA-MS type), fallout coupons or soluble gels. Assays will be performed according to NASA standard procedures for the microbiological examination of space hardware (Reference 12). Microbial test results will be correlated with particulate/aerosol monitoring results (Royco or other methods).

During manned testing, onboard monitoring will involve the same type of techniques as above; however, subculturing of primary isolates will be

performed post-test. Colony counts and presumptive identification, via 1) microscopic examination of stained smears, 2) gross morphology, 3) initial growth on differential agar media especially for fungal recovery, and 4) aerobic and anaerobic incubation will be performed in the onboard laboratory.

Sampling points will include those before and after microbiological filtration systems, the catalytic burner, and other microbe-reducing elements. Special sampling ports will be developed to take these samples. Sampling intervals will be correlated with periods of crew and subsystem operations which promote microbial aerosolization.

Immediately post-test and daily thereafter for (TBD) days, the atmosphere will be monitored in the test chamber interior.

#### 3.6.2.3 Surface and Equipment Monitoring

Microbial contaminants on surfaces and associated with hardware subsystem components will be monitored for determination of changes in levels and types affecting 1) crew health and safety, 2) materials deterioration/fungus resistance, and 3) performance control features in various environmental subsystems.

As part of the pretest contamination control program (cf. 3.6.2.1), samples should be taken of interior surfaces and representative subsystem components. Sampling procedures like Rodac plate, swab-template, swab-rinse, piece-part, soluble gel, detachable stainless steel strips, and other (TBD) experimental methods will be used. Assays will be based on NASA standard procedures for microbiological examination of space hardware (Reference 12).

During the manned test, onboard monitoring will involve the same type of techniques as above; however, subculturing of primary isolates will be performed post-test. Colony counts and presumptive identification via 1) microscopic examination of stained smears, 2) gross morphology, 3) initial growth on differential media, especially for fungal recovery, and 4) aerobic

and anaerobic incubation will be performed in the onboard laboratory. A statistical sampling program, designed to determine buildup or load in a specific subsystem vs. usage time, will be followed.

Immediately post-test and daily thereafter for (TBD) days, surfaces and equipment will be sampled and assayed. In addition, visual inspection of piece-parts will include examination for gross biodeteriorative effects.

#### 3.6.2.4 Potable and Wash Water Monitoring

Continuous monitoring of the potable water recovery subsystem for microbiological contaminants is essential to insuring that water consumed by the crew meets the NASA potability standard. The contamination in wash water also heavily impinges on maintaining crew health and safety.

During the 60- and 90-day tests, potable water samples were taken almost daily at various distribution points. During the 60-day test, no onboard tests were run. Contaminants were uniformly Gram negative rods, especially species of Pseudomonas and Achromobacter. Onboard monitoring was performed during the 90-day test using Millipore field monitors and a developmental chemiluminescent device for bacterial detection. Predominant contaminants in potable water were species of Alcaligenes and Pseudomonas; those in wash water were species of Alcaligenes, Pseudomonas and Bacillus. Remedial measures were applied in time so that the crewmen drank water which met the potability requirements of 10 viable microorganisms per ml or less. Post-test analyses of sundry water multifiltration and subsystem components yielded these same organisms and also E. coli and species of Staphylococcus, Sarcina, Bacillus, Corynebacterium, Actinobacillus, and yeasts. Potable water samples analyzed in an outside laboratory were negative for viruses but yielded cytotoxic effects in tissue culture cell lines.

As part of the pretest contamination control program, surface and equipment samples from the water management subsystem will be taken and assayed. When available, water samples from various distribution points will also be taken to monitor improvements in design and germicidal



treatment of water, e.g., ion exchange resins, chemical additives like iodine or silver or chlorine, laser irradiation, etc. Special sampling ports will be developed to improve sample collection, e.g., Millipore sterile tank sampling port.

During the manned test, onboard monitoring will involve techniques selected after pretest evaluations. Determinations of viable and total cell counts for both bacterial and fungal contaminants will be necessary for certification of potable water supplies by the Test Medical Director. A statistical approach to sampling and analyzing will be used. The onboard laboratory, which will not provide for subculture of primary isolates, will allow for preservation of cultures and water samples until post-test analyses. Colony counts and presumptive identification via 1) microscopic examination of stained smears, 2) gross morphology, 3) initial growth on differential media, and 4) aerobic and anaerobic incubation will be performed onboard.

Immediately post-test and daily thereafter for (TBD) days, water management system surfaces, hardware components, and various water supplies will be sampled.

### 3.6.3 Microbial Control in Stored Wastes

The waste management system provides for collection, treatment, storage, and disposal of fluid wastes, feces and cabin trash--all sources of potentially pathogenic microorganisms. During the 60-day test, no microbiological testing of stored wastes was performed. After the 90-day test, samples were taken of fecal bag contents (treated with Wescodyne) and stored wet food waste (treated with Quinolinol). Analyses showed that these materials were not sterilized, probably due to inadequate application of the germicides. The need for further evaluation of time vs. concentration effects of one or more antimicrobial agents was indicated.

Pretest studies using indicator organisms and prototype waste materials will be conducted to evaluate various treatment techniques and acquire baseline data.

Approaches to be considered include: lyophilization, germicidal spraying or immersion, hermetic sealing, dry or moist heat, UV irradiation, gas treatment, and storage at  $-70^{\circ}\text{C}$  or  $-195^{\circ}\text{C}$  (liquid  $\text{N}_2$ ).

Selected waste treatment methods will be applied and further evaluated during the test. Microbiological samples will be taken and processed in the onboard laboratory or preserved for post-test analysis. Laboratory wastes will include stains, used culture media, paper wipes, filter membranes, and disposable syringes and pipettes. Note: The autoclave in the pass-through lock could also be used for waste treatment.

Following completion of the closed chamber test, samples taken during the test and post-test will be analyzed.

#### 3.6.4 Potential Special Studies

Besides baseline studies primarily conducted to monitor and insure the health and safety of the crew, experimental studies of special scientific interest could be conducted during future manned tests. A list of potential special studies is indicated in Table 11.

### 3.7 CREW INTEGRATION

This effort consisted of a critical review of crew integration material in the Test Plan and Final Report of the 90-Day Test and identification of incongruities between 90-day procedures and those required for the 4-week test. Improvement in 90-day test procedures were sought to satisfy 4-week test objectives and to plan the future test consistently with the findings of the 90-day test.

The following material identifies major differences between the 4-week test plan and the 90-day test plan and supplies rationales for the selected approaches.

TABLE 11  
POTENTIAL MICROBIOLOGICAL SPECIAL STUDIES

<u>STUDY</u>	<u>METHODS/REMARKS</u>
1) Scan electron microscopic examination of hardware surfaces and components	Pre- and post-test examination for detection of biodeteriorative effects.
2) Development of onboard lyophilization capability	Hardware/engineering approach + biological testing of preservation procedures.
3) Pretest antibiotic sensitivity testing	Strains of organisms isolated during crew screening might be useful in finalizing list of antimicrobial agents in onboard medical kit.
4) Immunology	<p><u>Pretest</u> Immunological history of crew candidates plus immunoassays of sera might be useful in assessing immunity to medically important organisms.</p> <p>Possibility of crew vaccination.</p> <p>Crew quarantine periods.</p> <p><u>Onboard Laboratory</u> Fluorescent antibody tests.</p> <p>Slide agglutination.</p> <p>Tests for bacterial toxins in water samples, e.g., precipitin test for staphylococcal enterotoxin using agar gel diffusion method.</p> <p>Serum storage at -70° for:  Contingency testing  Study of antibody titer changes in paired sera for viral studies</p>
5) Viral and mycoplasma tests	<p>Throat washings, urine and fecal samples stored at -70°C for contingency testing.</p> <p>Evaluation of viral concentration and preservation methods for potable water samples.</p> <p>Development of techniques for recovery of viruses and mycoplasmas in tissue culture cell lines.</p>

TABLE 11

## POTENTIAL MICROBIOLOGICAL SPECIAL STUDIES (CONT.)

<u>STUDY</u>	<u>METHODS/REMARKS</u>
6) Recovery of anaerobic populations	Via consultation with Virginia Polytechnic Institute and State University Anaerobe Laboratory or Wadsworth V.A. Hospital/UCLA Medical Center
7) Prototype microbial detection devices	<p>LaRC chemiluminescent sensor for water bacteria.</p> <p>Aerojet - Microbial Ecological Monitoring System (MEMS) for real-time identification of viruses.</p> <p>MDAC-East - Microbial Load Monitor (MLM) (Ref. 13)</p> <p>Test for 5-10 most successfully identified organisms from mixed populations which include:</p> <p><u>Staphylococcus aureus</u>  <u>gamma streptococcus</u>  <u>Proteus sp.</u>  <u>Pseudomonas aeruginosa</u>  <u>Corynebacterium diphtheriae</u></p> <p>Using statistical sampling scheme, test nasopharyngeal swabs (see #9 below also), feces, potable and wash water, surfaces and hardware subsystem components.</p> <p>Identification of isolates via onboard MLM could be compared with classification by post-test analyses, using classical bacteriological methods and SANDIA or Apollo program computer identification schemes.</p> <p>Antibiotic sensitivity testing of isolates.</p> <p>Microscopic system providing projection of magnified field on screen outside of SSS (as discussed by Dr. J. Wilkins, LaRC).</p>
8) Cross-transmission/buildup studies with tracer or marker organisms	<p>Candidate organisms/marker features:</p> <p><u>Staphylococcus aureus</u> (coagulase-positive)  - phage typing  <u>Staphylococcus epidermidis</u> - TBD  <u>Streptococcus</u> - serological typing  <u>Bacillus subtilis</u> var. <u>niger</u> - colonial pigmentation  <u>Serratia marcescens</u> - colonial pigmentation</p>

TABLE 11

## POTENTIAL MICROBIOLOGICAL SPECIAL STUDIES (CONT.)

<u>STUDY</u>	<u>METHODS/REMARKS</u>
8) Cross-transmission/buildup	<p><u>Pseudomonas aeruginosa</u> - special recovery media (see below)</p> <p>Rhodotorula or other fungal spores - colonial pigmentation</p> <p>Radioactively-tagged micro-organisms</p> <p>Antibiotic sensitivity typing</p> <p>Dissemination by aerosolization or surface application; controls will account for loss of viability vs time</p> <p>Special recovery techniques for <u>Pseudomonas sp.</u>:</p> <p>Use selective cultural conditions</p> <p>Samples from: urine collection areas, crew dermal sites, potable and wash water</p> <p>Identify isolates by onboard MLM and compare with results of post-test analyses via classical bacteriological methods, computerized identification schemes, or gas chromatography (speciation by lactic acid curves)</p>
9) Study of special nasopharyngeal flora	<p>Collection and study of nasopharyngeal flora besides baseline test organisms; comparison of SSS findings with results of other NASA contracts:</p> <p>Dental Science Institute, U. of Texas (Reference 14-15)</p> <p><u>Candida albicans</u> and other fungi</p> <p><u>Mycoplasma sp.</u></p> <p><u>Lactobacillus sp.</u></p> <p><u>Veillonella sp.</u></p> <p>Others TBD</p> <p>MDAC-East MLM (see #7 above also)</p> <p><u>Staphylococcus aureus</u></p> <p><u>Gamma streptococcus</u></p> <p><u>Corynebacterium sp.</u></p> <p>Others TBD</p>

### 3.7.1 Onboard Crew Screening and Selection

Onboard crew screening and selection will be a multiphase operation as was accomplished for the 90-day test and will involve medical examination, psychiatric examinations, and evaluations conducted throughout training. Consideration will continue to be given to motivation, emotional stability, homogeneity of personality characteristics, and skills consistent with the requirements of the program.

Preselection screening of the onboard crew candidates was considered to be an important factor in ensuring a high level of motivation to participate in the 90-day test. It is believed that the large amount of screening and the difficulties of scheduling one's time to meet the screening requirements of test-taking and examinations were of value insofar as they tended to eliminate those whose motivation was less than adequate for participation.

A change between this selection process and the 90-day process is that females will be permitted to apply and they will be actively and seriously considered as potential crew members.

Pretest psychodiagnostics will consist of objective tests only. In the 90-day test, projective tests were of questionable value to crew selection or to the determination of emotional stability. Pretest psychodiagnostics will consist of the Minnesota Multiphasic Personality Inventory, FIRO-B, the Sixteen PF (Forms A and B), the Allport-Vernon Study of Values, the Rokeach Dogmatism Scale, the Edwards Personal Preference Schedule, and the Rotter I-E Scale.

The Motivation Analysis Test and the Eysenk Personality Inventory, which were considered of dubious value for selection and for the measurement of personality changes occurring during the 90-day test, have thus been eliminated.

The purpose of psychodiagnostic examinations is threefold. First, they serve as a basis for establishing the emotional stability of applicants and thus contribute to the selection process; second, they serve as a baseline from which legal liability can be established for personality changes which might be occasioned by the confinement to be undertaken; and third, they assist in determining crew makeup. Psychodiagnostics will also be performed post-test on all onboard crew members.

Another feature of the selection program which will differ from the previously conducted process is the timing involved in the appointment of a crew commander. For the 90-day program, the crew commander was selected at the same time as the onboard crew members, shortly before the test start. For the future test, it is deemed advisable to attempt to identify a crew commander early in the training program to allow for the development of a crew hierarchy which can be observed and evaluated throughout the training program. The crew commander role will be more specifically defined than on the 90-day test. For example, throughout training he will be involved in all decisions regarding crew performance and special task assignment and will be delegated the responsibility to allocate, reallocate, and reschedule tasks during the checkout and the extended test consistent with meeting the objectives of the test. He, of course, will also serve as the interface between test management personnel and the onboard crew.

The screening procedures included in the Preliminary Test Plan have been reduced by the elimination of several of the screening questionnaires which had been supplied by various investigating agencies (NMRI, NMNRU, TCU). While perhaps of value in increasing the difficulties of achieving membership in the candidate crew member pool and providing research data, they contributed little to the selection of the 90-day crew members. Only those questionnaires which were of value in selecting potential crew members for the 90-day test and which meet the further criterion of holding potential

value for the selection of crewmen for the extended test have been retained. These include: a medical questionnaire, the Cornell Medical Index, which has available forms for both men and women; a Biographical Survey, which contains biographical items extracted from a number of questionnaires; the Myers Inventory, a listing of 79 items providing information on behavioral patterns of applicants and their likes and dislikes; an Opinion Survey taken from the Naval Medical Research Institute "Studies on Confinement", which provides information on compulsivity in behavior and competitiveness in personality; and the Life Crises Inventory deriving from Naval Medical Neuropsychiatric Research Unit experience in the selection of Antarctic personnel, which provides information on stability of life styles. The above tests were of significant value in eliminating potential applicants prior to interview, which considerably reduced the interview time necessary to identify those candidates to continue through the screening procedures and were of additional value in identifying a relatively homogeneous crew in terms of similarities in life style.

Thus eliminated are the Fitzgerald Experience Inventory, which was not believed to contribute materially to the selection of 90-day crew members; the Hobby Inventory derived from the Naval Medical Neuropsychiatric Unit, which was neither of value in selection nor in the identification of likely recreational activities during the 90-day test; and certain questions from the Biographical Inventory, which were unnecessarily redundant.

In order to overcome a difficulty which occurred during the 90-day test screening (loss of applicants from the pool because of previous educational commitments), we have added the requirement of concurrence by faculty advisors should the applicant be a graduate student. The test plan indicates that no applications will be accepted from a graduate student whose studies will not be completed by the time the training program begins unless it has been countersigned by his appropriate faculty advisor or department chairman. Hopefully, this will tend to eliminate applicants who will encounter resistance at some future time by their school departments.



After return of the questionnaires indicated above, applicants will be invited to a personal interview which will consist of a dual approach to selection based upon the pragmatic criteria of suitability for the program in terms of skills and educational level, as well as a brief medical interview to determine the physical health of applicants and to identify existing health problems.

While these changes in procedure will contribute to streamlining the screening of applicants, they are similar in the amount of annoyance engendered by the application procedure of 90-day crew applicants. The result of the reductions in screening tests from a cost standpoint is negligible since those tests which have been omitted were scored during the 90-Day Test Program at the various requesting agencies.

The test plan indicates the retention of six applicants throughout the program. The selection of this number was based upon previous experience related to attrition within the personnel groups identified for this test. While the rate of attrition is expected to be small, it must not be totally disregarded. Health problems might occur late in the program which would require the elimination of an onboard crew member. Should attrition fail to eliminate these "backup" crew members, their training and skills will be put to constructive use as members of the support team and as potential experimental controls throughout the program.

### 3.7.2 Selection of Operating Staff

The Operating Staff positions, consisting of a Test Conductor, Medical Monitor, Communications Monitor, Engineering Monitor, and a Technician, are the same as used in the 90-day test and have the same responsibilities. Review of the 90-day test results indicates no deficiencies in the manner in which they were selected. Therefore, for future tests it seems appropriate that these positions (except for Medical Monitor) be staffed by selecting qualified and appropriately experienced engineers, technicians,

and scientists from within the contractor's organization. Medical Monitors should be selected primarily for their medical proficiency and interest as determined through interviews with the Program Medical Director. They must, of course, be licensed physicians. Previous experience has been excellent with contract hires as Medical Monitors.

### 3.7.3 Training of On-Board Crew

Differences in the crew training program beyond those of the 90-day test include full-time (40 hours/week) training, as opposed to part-time (20 hours/week); increased cohesion training; and the use of a relatively standardized test of achievement administered repeatedly throughout training.

Full-time training will be of benefit to the overall program in that it will provide crew availability for training and for obtaining baseline medical and microbial data at all times during the normal work week. Training was somewhat compromised, prior to the 90-day test, as a result of difficulties in matching the schedules of the crew pool with those of principal investigators. Mismatching of schedules is felt to be a function of difficulties in knowing precisely when equipment and instructors can be available for training insofar as subsystem qualification is the primary responsibility of the instructors who are also often principal investigators. While a full schedule of training activities will be developed by the training director for the crew, the full-time availability of crew members will allow rapid rescheduling of courses to take advantage of training opportunities with subsystems when the opportunities arise. It is felt that this approach is consistent with needs for training thoroughness and efficiency for the program.

The increase in the number of cohesion training sessions is in response to crew comments, after the 90-day test, indicating a desire for greater attention to this effort to aid in promoting smooth onboard interpersonal interactions. Another supporting rationale is the hope that increased cohesion

training will have a beneficial effect in enhancing crew morale during confinement and serve as the basis of increased crew satisfaction during test participation.

The use of a standardized achievement examination, which will be developed prior to the initiation of training, will serve the purposes of identifying crew pool deficiencies early in the program, measuring training progress, orienting the training material in terms of emphasis of course material, and assist in the selection of competent, motivated onboard crew members.

#### 3.7.4. Training of Operating Staff

The training of the operating (or support) staff will be accomplished as it was for the 90-day test with the only significant differences being an increased effort at improving the quality of course content, and a more thorough review of training accomplishments and expertise of operating staff candidates prior to certification, and a more extensive systems checkout period to improve cross training of staff members.

The first will be accomplished through review and approval of course material by the Program Manager or his designee(s) prior to the initiation of instruction.

The second will be accomplished through the conduct of a certification board which will review and evaluate knowledgeability of operating staff candidates after their participation in training. The certification board will be composed of program management and selected principal investigators. Its function will be to evaluate each potential support crew member through interrogative review of critical aspects of the support staff training program. When it has satisfied itself that sufficient expertise in support function has been achieved, and only then, it will certify the acceptability of that employe for a specific position(s).

Another function of the review board will be to decide upon the makeup of operating staff teams for each crew shift. This will be based upon considerations of employee preferences, degree of expertise demonstrated, personality capabilities and skills complement.

With regard to the third item, it was noted at the start of the 90-day test that many of the staff members had specialized in the development of specific subsystems, or concentrated their efforts in other limited areas, and too often were not familiar with other areas of the program. The proposed all systems checkout period is expected to improve the cross-training of staff members as well as to identify weaknesses in the hardware and operating procedures.

### 3.7.5 Habitability Requirements

The habitability subsystem consists of that hardware provided and configured within the simulation chamber to meet the habitability needs of the onboard crew. For purposes of this report, the following elements comprise the habitability subsystem:

- a. Volume, area and configuration of the space.
- b. Food Management
- c. Personal Hygiene and Laundry
- d. Recreational provisions
- e. Crew Furnishings and Accommodations
- f. Sleep Facilities
- g. Housekeeping and Waste Collection
- h. Lighting and Decor
- i. Clothing and Linens
- j. Atmospheric Conditions
- k. Storage facilities

During this study, each of these elements was examined individually to determine the optimum configuration for a habitable environment for the forthcoming 4-man test. This involved review of the results of the 90-day test and a comparison of alternatives available.

Trade studies were made where appropriate and these are discussed in the subsections which follow.

Evaluation of the effectiveness of the final habitability subsystem in meeting the needs of the crew is a necessary part of the entire program. The methods selected and the analysis which contributed to that selection are described.

### 3.7.5.1 Habitability Design

#### 3.7.5.1.1 General Configuration

Studies in general configuration assumed that the Phase A test would be performed in the same vehicle or one of similar configuration as was used in the 90-day test. The  $115 \text{ m}^3$  (4100 cu ft) of volume is divided by a bulkhead at a point approximately 4.6 m (15 ft) from the forward (or equipment compartment) end, which provides  $42.5 \text{ m}^3$  (1517 cu ft) of volume in the equipment area, and  $72.3 \text{ m}^3$  (2583 cu ft) of volume in the crew quarters area. The following unique features of the forthcoming test required consideration:

- a. The addition of a shower
- b. Addition of expanded onboard medical laboratory facilities
- c. Need for closer monitoring of selected life support system parameters
- d. Possibility of mixed crews.

Various configurations for accommodating the shower were evaluated. It was assumed that the shower enclosure would be provided GFE, but no exact dimensions are available. Review of zero-g shower concepts described by Martin, Grumman, and Fairchild Hiller indicated that the enclosure might require as much as  $0.94 \text{ m} \times 0.94 \text{ m}$  (3 ft x 3 ft) of flat floor area and a height of 2.2 m (7 ft). It was felt highly desirable to locate the shower within the personal hygiene area used in the 90-day test. With these considerations in mind, it became necessary to relocate the commode and urinal. These were located adjacent to the personal hygiene area, but on the equipment compartment side of the acoustic bulkhead.

Expanded onboard laboratory facilities are needed because no passouts will be permitted and certain laboratory tests previously done in outside labs will now have to be performed onboard. In order to have sufficient space and to centralize the lab functions, the onboard lab area was allocated space along the entire right wall from the forward end of the chamber to the acoustic bulkhead.

Monitoring of the life support subsystems was accomplished during the 90-day test via the crew life support monitor console located at the forward end of the equipment compartment. There was some indication that completely adequate monitoring was not achieved since much of the time no crew members were in this compartment or were otherwise occupied. One solution to this problem is to assign a crew member to continuously monitor the life support console. Another proposed solution was to move the console into the crew quarters area where it would be convenient for a crew member to always be in the immediate vicinity. Analysis of the crew time requirements imposed by the alternative solutions dictated the relocation solution as the method of choice.

Considerable study and discussion of the impact of mixed crews on the general configuration resulted in the conclusion that no major changes are required to accommodate mixed crews, but special attention needs to be given to providing privacy in the personal hygiene and sleep areas.

#### 3.7.5.1.2 Food Management

Study of the food management subsystem for the 4-week test has centered upon the maintenance of high hedonic acceptability, balanced and known nutritional values, ease and safety of preparation and waste management, packaging, and microbiological control compatible with requirements for a closed system.

Success with the food management program of the 90-day test prompted contact with the supplier of the 90-day food, which was Oregon Freeze-Dry Foods, Inc., Albany, Oregon. In order not to eliminate potential competitive

bids, another supplier was contacted who had experience in the provisioning of space foods: Whirlpool Corporation, St. Joseph, Michigan.

Bids were received from both of the respective vendors. The Oregon Freeze-Dry bid indicates the availability of a diet similar to the diet employed during the 90-day test. Major differences are improvements in certain food items and the analyses required to identify nutrient constituents. The Whirlpool Corporation bid provides for the inclusion in the 4-week test of Skylab-type food and includes analytical data on carbohydrates, fat, protein, calcium and phosphorus. Skylab-type food consists of frozen, wet-pack, dry and freeze-dehydrated foods requiring suitable storage provisions. The Oregon Freeze-Dry food consists primarily of freeze-dehydrated foods with addition of dried snacks.

It is recommended that Oregon Freeze-Dry be the supplier of food for the Phase A test, and related planning has been based upon this assumption. Reasons include competitive price, high acceptability, as demonstrated during the 90-day test, and ability to provide needed constituent analyses.

Differences in the food management program for the Phase A test versus the 90-day test include the following: reduction in the number of flammable, disposable utensils and dishes through the introduction of reusable dishes; reduced food storage requirements; packaging to provide a meal for two crew members in each package; and increased attention to the accuracy of caloric determinations.

Consistent with the duration of the Phase A test and reactions of the crew to a mixed (2-storage technique) food program, it is recommended to restrict the baseline diet to freeze-dehydrated foods only. Thus, high morale meals are deemed unnecessary for the purpose of the 4-week test and have been eliminated. The supplementary or snack portion of the diet, however, will consist of high morale items, such as ice cream, nuts, dried fruits, and candy bars.

Techniques for handling food waste were reviewed and alternative approaches investigated. Crew members will be encouraged to consume all prepared foods. In the event that certain portions are not consumed, these portions will be weighed and then heated on Teflon or Teflon-coated dishes in the microwave oven until the food remnant has been desiccated on the surface of the dishes. When desiccation is complete, the dishes will be removed from the microwave oven, food remnants will be scraped from the surface of the dish and stored in either the cans of the on-board canner for later autoclaving, or will be disposed of with appropriate pretreatment in the dry waste storage cannister.

Consideration was given to reduction of the flammability of food packaging, which was a significant problem in the 90-day test that was met by wrapping meal-sets in multiple layers of heavy aluminum foil. Oregon Freeze Dry has indicated that alternate packaging materials could be supplied which would reduce the flammability hazard, but because of unknowns in characteristics of using those materials with their current vacuum packaging equipment, costs cannot at this time be estimated. Further discussions with MSC and Oregon Freeze-Dry seem to be in order to identify existing materials which could be employed by Oregon Freeze-Dry at minimal additional cost for food storage and packaging.

As before, it is recommended that all food will be heated or reheated on-board with the use of a microwave oven. This will, of course, require frequent radiation monitoring to assure that radiation emissions are below the allowable standards. As a backup to the microwave oven, a resistance-type hotplate unit will be supplied.

All foods ultimately selected for use onboard the Phase A test should continue to be selected from the standpoints of palatability as defined in the 90-day test report, microbiological compatibility, and nutritional value. Foods should be selected with concurrence of potential crew members and should be taste-tested by them prior to stowage on-board the simulator.



#### 3.7.5.1.3 Recreational Provisions

Recreational provisions beyond those described in the Test Plan under the portion entitled, "Communications System", include an on-board library, books to be supplied by the crew members and stored in non-flammable containers; board games to be selected by the crew members prior to the test and reviewed for flammability and outgassing characteristics; the Langley Research Center Psychomotor Complex Coordinator, which was a successful recreational adjunct during the 90-day test; certain hobbies (kits) which are desirable and prove to be compatible with the environment; and an onboard commercial broadcast color video receiver.

#### 3.7.5.1.4 Personal Hygiene and Laundry

During the 90-day test, bathing was accomplished by the use of wet washcloths. At the post-test debriefing, the crew agreed that the inclusion of a shower in the forthcoming tests would be a welcome improvement.

Several problem areas associated with the onboard shower were investigated during the study. These include space requirements (shape and dimensions), frequency of use, quantity of water required, water purity, spray nozzle type and location, cleansing agents, and water temperature. The available literature on space shower design was reviewed and is summarized in Table 12.

The problem of providing space for the shower was discussed under General Configuration (Section 3.7.5.1.1). To be maximally acceptable, the shower should be available to be used as frequently as the crewmen desire. With the assumption that each shower will require from 2.3 to 3.6 Kg (5 to 8 lbs) of water, it is reasonable to permit daily showering by the crew.

Other hygiene and laundry provisions are similar to those of the 90-day test and are described in the Preliminary Test Plan CR-111999.

They feature ingestible dentrifice, electric razors, and a commercial washer and dryer for laundry. The possibility exists of using a space-type washer-dryer, presently being developed by Whirlpool Corporation, as an advanced subsystem.

TABLE 12

## SPACE SHOWER DESIGN LITERATURE

<u>PROBLEM AREAS</u>	<u>MARTIN</u>	<u>FAIRCHILD HILLER</u>	<u>GRUMMAN</u>	<u>SSP GUIDELINES</u>
DIMENSIONS, SHAPE, & VOLUME	TAPERED RIGHT CYLINDER 0.87 m <sup>3</sup> (30.9 Cu.Ft.)	CYLINDER .9 m x 2.2 m (36" DIA 84" HIGH)	.77 m (30") DIA CYLINDER 2.2 m (7') HIGH 1.24 m (44 CU FT)	(NOT STATED)
FREQUENCY OF USE	(NOT STATED)	3 TIMES/WEEK/ MAN	1/WEEK/ MAN MIN.	ONCE/DAY/MAN
QUANTITY OF H <sub>2</sub> O REQUIRED	2.0 Kg/SHOWER (4.5#)	9.1 Kg/SHOWER (20#)	(NOT STATED)	3.6 Kg/SHOWER USE (8#)
WATER PURITY	(NOT STATED)	(NOT STATED)	(NOT STATED)	MUST MEET POTABILITY STANDARDS
SPRAY NOZZLE	HAND HELD MOVABLE NOZZLE	FIXED OR HAND HELD	RING OF SPRAY NOZZLES	(NOT STATED)
WATER TEMP	37.2 - 43.3°C (99 - 110°F)	(NOT STATED)	CREW CONTROLLABLE	32.2 - 43.3°C (90 - 110°F)
CLEANSING AGENT	LIQUID, BIOSTATIC, LOW SUDSING	(NOT STATED)	(NOT STATED)	CASTILE SOAP OR MIRANOL C2M

#### 3.7.5.1.5 Crew Furnishings and Accommodations

Furniture and crew accommodations provided in previous tests was reviewed for adequacy and applicability to the forthcoming test. In general the requirements for these items are not changed over those for the 90-day test and no serious complaints from the on-board crew were received. Therefore crew furnishings and accommodations will remain unchanged except for the two items discussed below.

The microphones previously supplied to the crew were criticized because of the pickup of background noise. To correct this problem microphones for the forthcoming test will be noise canceling and will have a press-to-talk capability.

Design for privacy will receive more attention primarily in the sleep area where some irritation was expressed by previous crews. To satisfy these objectives and to provide necessary privacy in the event of mixed crews the individual bunks must be acoustically and light isolated from each other and from the remainder of the crew quarters.

#### 3.7.5.1.6 Sleep Facilities

In the 90-day test four bunks were provided, one for each of the crewmen. A curtain separated the sleeping area from the rest of the crew quarters and was designed to act as an acoustical as well as a light barrier. There were no curtains for the individual bunks. The curtain was not completely effective in either noise or light attenuation and some complaints were expressed by the crew.

The requirement for expanded onboard lab facilities necessitated an evaluation of what other areas might be reduced in size. The sleep area became prime candidate for reduction, if the number of bunks could be reduced from four to two and dual occupancy (hot bunking) utilized. Figure 19 illustrates the space saving available. Such an arrangement is only possible if the work/rest

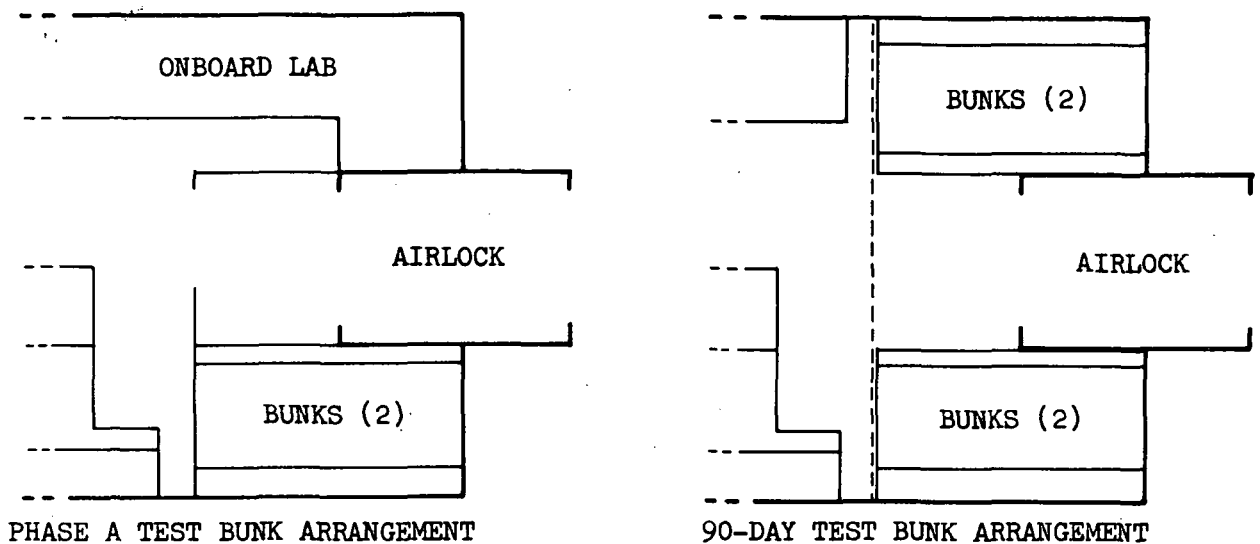


FIGURE 19 REDUCTION IN SLEEP AREA FOR PHASE A TEST

cycle calls for only two men to be sleeping at any one time, so this factor had to be evaluated with the trade study on work/rest cycle. As indicated in Section 3.2.3 the work/rest cycle selected does permit the use of only two bunks.

To facilitate efficient use of the sleep area on a dual occupancy basis it was decided to substitute for the bed linen approach used in the 90-day test a concept of individual bedrolls which could be stored near the bunk area when not in use.

As can be seen from Figure 19, the floor space and volume remaining for dressing and undressing and for storage is limited. This area was expanded by removing the inner air lock door. This will provide additional area especially for hanging storage of clothes items, which was one of the facilities lacking in the 90-day test and which annoyed the crew. This is acceptable since, with the use of a cabin atmospheric pressure slightly above external ambient, the use of the airlock for inner chamber isolation is no longer required.

### 3.7.5.1.7 Housekeeping and Waste Collection

This element of the habitability subsystem includes the equipment and supplies, and associated procedures, for maintaining the interior of the simulator clean and orderly. During this study, 90-day test results in this area were thoroughly reviewed and investigation was made of promising advanced concepts for housekeeping and waste collection.

The equipment and supplies used for housekeeping in the previous test were adequate and received high acceptability ratings by the crew. Therefore, no substantial change is anticipated.

Waste material collected and processed during the 90-day test included dry and wet food waste. Various paper materials including toilet paper, expendable food trays, cleaning rags, used filter elements, aluminum foil, plastic containers, and miscellaneous waste materials. The approximate total volume accumulated during the course of the test is shown in Table 13.

TABLE 13  
90-DAY TEST WASTE VOLUME

<u>Item</u>	<u>Volume</u>	
	<u>m<sup>3</sup></u>	<u>(Ft<sup>3</sup>)</u>
Packaged Bundles	0.34	(12.02)
Waste Storage Containers	0.09	(3.18)
42 #2 Cans (Wet Waste)	0.03	(0.96)
Food Trays	<u>0.11</u>	<u>(3.82)</u>
Total	<u>0.57</u>	<u>(19.98)</u>

In addition to the shortened duration, several other differences in the makeup of waste products will exist in the Phase A test as it is presently planned. The item "Packaged Bundles" shown in Table 13 consists largely of used food packages. It was originally planned to use a Dry Waste Baler for this packaging, but as the test progressed the baler was not used.

Food packages and other dry wastes were wrapped in aluminum foil food wrapping and stored in the empty food compartment. Thus, it is not considered necessary to include the baler on future tests.

Various waste compactor concepts presently under study or in development were investigated. The MDAC Space Station Trash Compactor concept, based on the accumulation of  $0.11 \text{ m}^3$  (4 cu ft) of trash per day for a 12-man crew, uses space vacuum for initial processing and then uses 8,900 N (2,000 lb) force to compact each  $0.11 \text{ m}^3$  (4 cu ft) volume to  $0.03 \text{ m}^3$  (1 cu ft). The need for a trash compactor is predicated on long-duration and large crews with consequent accumulation of large amounts of trash. Evaluation of such a unit during extended manned testing would provide valuable data, but its use is not essential to the success of the Phase A program outlined herein.

The development of an engineering model of a Trash Compactor is presently being undertaken by Industrial Ecology, Inc., for LaRC and consideration was given during the study to incorporating this prototype with the Phase A habitability subsystem. However, it was decided to delay such incorporation until later Phase B tests in view of the uncertainty of delivery schedules. In any event, the volume of trash anticipated for the Phase A test can be adequately handled by the equipment described in the Preliminary Test Plan.

#### 3.7.5.1.8 Lighting and Decor.

Review of the lighting facilities provided in the 90-day test and the crew's response to the adequacy of lighting dictates that essentially the same lighting system be used again. As indicated in Section 3.7.5.1.5, however, improved light isolation will be provided in the sleep area.

A major crew criticism of decor in the 90-day test was that the interior was decorated as a laboratory and there was not sufficient distinction between working and living/recreation areas. It was recommended that (1) a sharp distinction be provided between living quarters and laboratory or equipment areas, and (2) decorative materials be utilized to provide enrichment of the visual and perceptual environment wherever possible.

Results of the 90-day test, as well as other confinement studies, verify that variety in the environment is one of the features most desired by occupants. Consideration was given to providing an interior decor and configuration which could be varied during the test at the discretion of the crew. Though such a capability appears desirable, especially in an experimental program such as the forthcoming test, cost considerations prevent its inclusion in the Phase A test.

To provide a more attractive decor than was available on the 90-day test, a careful selection program will be conducted to select colors and materials in the various areas to provide a distinction between the areas and to give a pleasant, tasteful environment in the crew living quarters.

#### 3.7.5.1.9 Clothing and Linens

Various types of clothing materials were evaluated in the 90-day test. The extensive material and tailoring costs involved in such a program do not appear justified for the Phase A program. Therefore, it is recommended that commercially available garments made of Nomex should be used. These garments should be selected for commodious fit to answer one of the crew criticisms of the 90-day test. It is anticipated that the crewmen will provide their own cotton undergarments, pajamas (if desired), and cotton socks.

One pair of soft-soled, heelless leather moccasins per crewman, similar to those used in the 90-day test, should be provided.

Because of the hot bunking provisions, each crewman should be supplied with a commercially available sleeping bag (covered with Durette), and a pillow and pillow case.

#### 3.7.5.1.10 Atmospheric Conditions

The only changes contemplated over those of the 90-day test involve additional effort to provide acceptable air flow control in the sleep area and greater attenuation of noise between the crew quarters and the sleep area.

### 3.7.5.1.11 Storage

A systematic, logical approach is required for the allocation of available storage space to the many loose items of equipment required in an extended mission. This is as true for a ground simulation mission as it is for an operational space flight. The following factors must be considered:

#### 1. Storage Space Available

- a. Location, capacity, and shape of each specific storage area.
- b. Environmental characteristics of each space (temperature, humidity, spark protection, air flow, etc.)
- c. Inherent accessibility (e.g., behind obstructions, beyond easy reach, etc.)

#### 2. Characteristics of Loose Items

- a. Size, shape, and weight
- b. Location(s) at which used
- c. Frequency of use
- d. Storage constraints (controlled temperature, humidity, etc.)
- e. Physical characteristics (liquid, solid, powder, etc.)
- f. Flammability and outgassing characteristics
- g. Storage configuration (folded, flat, hanging, etc.)

#### 3. Disposition of expendables or used items

- a. Reuse of vacated storage space
- b. Reservation of storage space
- c. Disposal as trash

A sophisticated system has as its objective the matching of (1) storage space available with (2) characteristics of loose items, and the efficient use of storage space vacated by expendables or spares. This element of the habitability subsystem interacts closely with the housekeeping element since a good storage system will encourage good housekeeping while inaccessible, poorly located, and inconvenient storage will encourage crewmen to clutter up the interior with items removed from storage rather than to return them to their proper storage place.



A preliminary study of available storage space in the reconfigured chamber was conducted. Because of relocations of certain equipment and changes in internal configuration, several areas available for storage during the 90-day test are no longer available, while several new areas have been opened up. The net effect is a small increase in available storage area. Initial enumeration of loose items requiring storage was begun by reviewing inventory lists from the previous tests and identifying those items which it appears will be retained. Additional review of plans for the Phase A test identified those new items which will require storage. A preliminary list of these items was compiled and is presented in Section 8 of the Preliminary Test Plan.

#### 3.7.5.2 Habitability Assessment

As one of the advanced subsystems to be included in the forthcoming test, the habitability subsystem must be subjected to the same rigorous evaluation as other subsystems. Each subsystem element must be evaluated, primarily against criteria of acceptability, but also in terms of equipment performance, maintainability, hazards to personnel, and damage or wear and tear.

The habitability assessment program used in the 90-day test was reviewed for applicability and needed modifications. A Habitability Questionnaire to which the crew responded periodically was the primary measurement method, although additional subjective crew evaluations were obtained in post-test debriefings. Before initiation of the next test, and after all elements of the habitability subsystem have been finalized, this Questionnaire will be completely revised and will be reviewed with the crew during training.

Objective measurements should be made in the evaluation of habitability to the extent possible. One of these involves measurement of the frequency with which crew members use facilities provided. The hypothesis here is that, given free choice, the crew member will use more frequently those recreational, food, personal hygiene, and other facilities which are most acceptable to him and that on-the-spot notation by an outside observer of

his actual choice is a more valid measurement than the crewman's recollection after the fact.

Other objective measurements include recording of atmospheric conditions as the test progresses, detailed post-test inspection of habitability subsystem hardware, recording by outside observers of problems encountered by crewmen in using habitability provisions, and verbal behavior reflecting an attitude toward portions of the habitability subsystem.

### 3.7.6 Behavioral Assessment

Behavioral assessments include all techniques which measure human reactions to the confinement situation. The techniques employ observation and measurement by outside personnel and on-board personnel and are discussed in that order. All techniques have been selected on the basis of the following criteria: Sensitivity to anticipated changes; minimum irritational content; value for procedural or design improvements for future tests or operational missions; and informative of the crew psycho-social state during the test.

#### 3.7.6.1 Measurement by Outside Personnel

A Communications Monitor Log Book was maintained during the 90-day test which was intended to provide project management personnel with daily impressions, by Communications Console Monitors, on crew social/emotional condition. The rationale for this approach was that the Communications Monitor was the person most continually in contact with on-board crew members and was thus expected to be a source of such impressions. In fact, it was difficult to obtain more than a brief subjective comment from each Communications Monitor per shift regarding on-board crew social/emotional status. Often, comments of the Communications Monitors dealt with work performance as opposed to emotional factors.

The Communications Monitor Log Book is considered a potential source of information which can be improved for the 4-week test. Improvements will be made through training of the Communications Monitors and through structuring of the Log Book entries such that information of value to project management can be more reliably obtained. Pre and post-test analyses of data will be provided.

Other observations by outside personnel consist of observations of the hardcopy received as output from the crew computer data link. This link will be employed by each crew member to enter data of various types, including questionnaire response data and information necessary for mass balance determinations. Attempts will be made to equalize the amount of data transmitted by each crew member. Review will be made of the hardcopy to determine proportion and type of errors in the transmitted information. This information will be maintained on a daily basis and will provide a basis for measurement of the quality of crew performance during the course of the mission. This approach will hopefully overcome one major difficulty of the 90-day test which was that a sensitive measure of work performance quality was unavailable through the collection of task accomplishment records only. The review of data link records will augment task accomplishment records which will also be maintained by the Communications Monitors.

#### 3.7.6.2 Measurement by Crew Members

Other information will be available on crew behavior during the test. This information will derive from two sources: psychomotor test data, and onboard diaries.

It is anticipated that the Langley Research Center Complex Coordinator will be available for use during the Phase A test. On the basis of this availability, it is expected that hardcopy data can be analyzed daily for each crew member to determine deviations from a pre-established asymptotic value for that crew member. Attempts will be made to correlate significant deviations from asymptote with simultaneous alterations in environmental parameters, or with changes in crew psychosocial status. Performance

asymptotes must be established prior to the test in order for data to be of value regarding psychomotor performance changes during the test. To that end, it is anticipated that alterations will be made to the Langley Research Center Complex Coordinator program such that asymptote can be achieved in considerably fewer trial runs than was the case during the 90-day test program. One anticipated change which seems feasible is the reduction in the number of trials per set. During the 90-day test, the number of trials per set was 100. With a reduction to one half that amount (50), it is expected that asymptote can be reached earlier during the training period.

Some of the onboard diaries from the 90-day test were a valuable source of information regarding crew social interactions and emotional condition during most of the test. However, in view of the dearth of information, especially during important periods of the test in certain onboard crew member diaries, an attempt should be made to structure the entry procedure of these so that information of greater value to post-test analyses can be obtained.

#### 3.7.6.3 Changes to Onboard Questionnaires

Many questionnaires were employed during the 90-day test to collect information regarding the quality of living aboard the Space Station Simulator, and to assist in the assessment of work performance. For the 4-week test, a review of the value of each of these questionnaires has been accomplished with the following findings. Certain tests were of limited or no value to the determination of crew condition aboard the simulator. These include the Descriptive Sentence Test, the Subjective Stress Scale, the Hostility Scale, the Isolation Symptomatology Questionnaire, Group Confinement Inventory, the Primary Affect Scale, and the IBR Personal Space Measure. The transparency of these tests and the ease of distorting results on many of them are a primary reason for their deletion from the 4-week test. Those tests which are retained have been determined to have been of value during the 90-day test. These include the Sleep Questionnaire, the Sociometric Test, the Food Questionnaire, and the Habitability Assessment Questionnaire. These should be retained with modifications made to them as required to suit the

purpose of the 4-week test. Another source of information on crew emotional condition should be a weekly interview with the Crew Integration Director. Results of this interview should be documented and made available to appropriate personnel.

#### 3.7.6.4 Post-Test Debriefings

Of significant value to determining habitability reactions and psychosocial integrity during the test, were the various debriefings conducted after the 5-day manned checkout and the post-test crew debriefing held following the 90-day confinement. As indicated in the test plan, debriefings will be held after the 100-hour test regarding engineering and habitability provisions aboard the simulator. This debriefing should be held under the direction of the Program Manager.

After the extended test, another engineering debriefing should be held, again under the direction of the Program Manager, concerning itself with responses to the habitat, operational subsystems difficulties, and habitability provisions. This debriefing should be open to principal investigators and cognizant government personnel. Results should be documented for future reference.

#### 3.7.7 Selected Areas for Potential Special Studies

Within the crew integration area, it seems unlikely that a 4-week test can be of significant value in providing new information on the effects of long-duration simulated spaceflight on man. However, the 4-week test can serve as a valuable test-bed for the development of operational techniques to measure human characteristics and their changes over time. Such techniques could be evaluated with regard to accuracy, data management requirements, instrumentation adequacy, and acceptability to crew members.

The following special studies have been identified as potentially desirable for incorporation as additional study efforts during the 4-week test.

Within each identified study area, a brief paragraph of descriptive material is provided to clarify the intent of the study and, where necessary, indicate the approach to be taken.

#### 3.7.7.1 Skylab-type Foods

It may be desirable to evaluate various aspects of Skylab foods (hedonic acceptability, preparation techniques, etc.) in advance of the Skylab mission. Preliminary discussions with cognizant personnel at the Manned Spacecraft Center have indicated an interest in an evaluation of the Skylab food system. The Whirlpool Corporation was contacted and has submitted a proposal indicating that Skylab foods and preparation systems (with flight-type packaging of the food items) would be available in advance of the 4-week test.

An approach would be to provide the Skylab food system for 2 men for half the mission while providing baseline food for the other two during the identical time frame. After a specified duration, assignment of food to personnel would be reversed.

#### 3.7.7.2 Ames Crew Evaluator (ACE)

Preliminary contact with personnel responsible for the development of the Ames Crew Evaluator (a psychomotor and intellectual skills testing device) indicates the potential availability for the Phase A test of a new device to measure human performance. An experimental design has not yet been developed; however, materials and reliability characteristics appear within the realm of successful resolution in time for adequate training and incorporation of this device in the test.

#### 3.7.7.3 Critical Task Tester (CTT)

Preliminary contacts with the vendor and cognizant personnel at Ames Research Center indicate the availability of the Critical Task Tester which was one of three devices used on the 90-day test for the measurement of psychomotor performance. An experimental design has not been developed but could be, consistent with the requirement to place this device aboard the chamber.

Experimenters are interested in evaluating alternate testing schedules and modifications to task difficulties. A preliminary proposal abstract has been developed, at MDAC request, by Systems Technology, Inc.

#### 3.7.7.4 Behavioral Acoustics Program

Findings from the 90-day test suggest that additional attention should be placed on the area of the effects of noises upon personnel during the 4-week test. Interest still resides in: temporary threshold shifts occasioned by prolonged exposure to NCA 50 and NCA 60 noise levels; the effects of intermittent noises on sleep quality; speech comprehension and general acceptability of communications and entertainment equipment; and subjective reactions to overall noise levels. A program suggested by personnel who previously accomplished the 90-day test behavioral acoustics program indicates that monitoring of noises and reactions to noises can be accomplished on the 4-week test in a fashion similar to that accomplished during the 90-day test, but with improvements, at a reasonable cost. The program would involve: physical measurement of noise levels aboard the space chamber; measurement of objective reactions of crew members to various noises; measurement of subjective reactions of crew members to noise levels; and correlations of these. An experimental design has not yet been developed.

#### 3.7.7.5 Electroencephalographic Studies

Results of the 90-day test indicate the desirability of collecting additional data on brain wave characteristics. The data can be a source of corroborative information on emotional states of onboard crew members.

A program can be developed using GFE or contractor furnished equipment to accomplish the goals of providing support staff personnel with continuous real-time analysis of EEG signals from sleeping or awake crewmen. During awake periods, it might be desirable to record EEG from personnel engaged in various standardized tasks, such as the Langley Research Center Complex Coordinator, ACE, or the Critical Task Tester. Attempts will be made to correlate EEG performance with psychomotor activity, or other psychophysiological indices of crew status.

#### 3.7.7.6 Non-Interference Performance Assessment (NIPA)

The 4-week test offers the opportunity to improve the NIPA technique, developed under the 90-day test program. During the 4-week test, efforts can be oriented toward reducing data collection requirements, enhancing the quality of audio signals, investigating the feasibility of automated voice analysis in the determination of emotional state, and determining the operational utility of real-time data display systems for the presentation of NIPA data to support personnel. As mentioned in other reports, the NIPA technique offers the potential of providing information on crew psychosocial integrity, and/or morale, on a real-time basis for use by program management in scheduling activities and/or modifying interactional characteristics of onboard and support crew members.

#### 3.7.7.7 Computerized Education

Ames Research Center, in association with the Stanford Research Institute, has developed a number of computerized learning programs for use by onboard personnel which are amenable to video display and teletype keyboard interaction. Interest has been expressed, at the Ames Research Center, in incorporating such learning programs in the 4-week test in an attempt at determination of their acceptability and operational difficulties. A program now exists for teaching computer programming and a language course. Neither of these courses requires any human support beyond the learner. In addition to providing information to the developers of these systems as to the acceptability of the approaches, it is desirable to incorporate such techniques to improve the diversity of crew recreational outlets.

#### 3.7.7.8 Nonmetallic Materials

As during the 90-day test, the opportunity exists to evaluate acceptability, wear characteristics, and contributions to interior decor characteristics of new materials under development at the Manned Spacecraft Center.



Interest has been expressed, by personnel of that Center, in applying new materials to the Phase A chamber test in order to provide information on continuous acceptability of these materials for a one-atmosphere environment. Newly developed fire retardant materials include: a simulated wood-grained surface coating material with non-outgassing adhesive backing; textured paints for application to aluminum surfaces which are of potential value in increasing surface texture interest for onboard crew members; a fire retardant transparent plastic food packaging material; and various garment materials for crew clothing. Other potential new materials which could be tested in the 4-week test include: floor covering materials; acoustic dampening foam, which will meet current outgassing specifications; and new bedding material.

#### 3.7.7.9 Habitability Concepts

Numerous possibilities exist, with the 4-week testbed, to evaluate various Habitability Subsystem design concepts under development at different NASA centers. Particularly amenable to testing and evaluation are: illumination, interior design, and surface color concepts. Included are: concepts on lighting intensity and placement, illumination chromaticity, surface color selection, privacy accommodations, hygienic provisions, and sleeping accommodations.

The advantage of an extended test over other possible tests of habitability concepts (walkthrough evaluations) is that an opportunity exists for continuous evaluation of crew response. Thus habituation, or changes in use occasioned by operational task requirements, can be accounted for.

Of some interest may be the relationship between workload and habitability support insofar as they interact toward the acceptability of a particular habitat. Workload can be altered (dependent upon the requirements of a habitability experiment) to provide information on the contribution of

workload to the acceptability of habitat provisions. The 4-week test communications system lends itself to habitability studies by providing continuous audio and video monitoring for objective and/or subjective measurement of crew interaction with the environment.

Efforts could also be directed toward determination of the adequacy of existing Habitability Design Manuals. The chamber interior could be designed using MSC-generated manuals and evaluations of these could be provided. Of interest are: information sufficiency, clarity of presentation, redundancy of data and data omissions.

#### 3.7.7.10 Mockup

During review of the crew training and engineering integration requirements for this study, it has become apparent that it would be desirable to have available a full-scale soft mockup of the simulator. Its purpose would be for evaluation and development of subsystem interface requirements, habitability design concept studies prior to firming them for use inside the test chamber, and for training on prototype or soft mockups when operational subsystems are unavailable because of bench testing or integration in the chamber. Another valuable feature of this soft mockup would be its availability for walkthrough purposes during the 4-week test for visiting dignitaries. A soft mockup could contribute significantly to the accomplishment of the 4-week test.

#### 3.7.7.11 Crew Selection

Additional data can be collected, analyzed, and compared with material generated on the 90-day test and other programs (Tektite) on the issue of psychological devices aiding in crew selection. Crew members could be made available for additional testing using devices supplied by other experimenters and results of these devices could be compared with results developed on previous programs. Although it is not expected that a crew selection experiment will definitively resolve the issues within the area, the addition of the 4-week test subject pool will contribute to increasing the validity of such selection approaches.

### 3.8 DEFINITION OF DATA MANAGEMENT REQUIREMENTS

This section deals with data management requirements for Phase A and Phase B tests. The requirements strongly reflect experience gained during the 90-Day Test where certain inherent weaknesses existed. Tasks required for both tests are outlined and equipment options are discussed. Specifications have been formulated for the Phase A test portion.

#### 3.8.1 Ninety-Day Test Data Management

Data management on the 90-day test consisted basically of off-line processing except for the mass balance, food, and behavioral subroutine which processed on-line. A low speed digital system (LSDS) scanned approximately 200 channels each 30 minutes and stored the data on magnetic tape. The tape was processed daily on an XDS 930 where engineering unit conversion and limited performance data was calculated and printed. A CRT/KEYBOARD (i.e., acoustical data link) unit connected to the XDS 930 was utilized for mass balance, food, and behavioral program input data. This input was made on a daily basis at a scheduled time. Output from the computer was not displayed on the CRT's.

Inherent weaknesses existed in the 90-day test data management system. The major weaknesses were: 1) limited flexibility of the mass balance subroutine, 2) limited "real time" access to the computer, 3) lack of display of data and processed information on the CRT, 4) limited scope of capabilities (i.e., no trend analysis, or fault isolation), 5) lack of common program with sub-routines for handling total data management.

A modernized approach to data management for the Phase A and Phase B test must correct the above deficiencies if the objectives outlined in Section 3.1 are to be met.

### 3.8.2 Task Breakdown

An analysis of the overall data management tasks for Phase A and Phase B tests were made during the study. They are discussed as follows:

#### Task 1. Data Control

##### Subtasks:

- 1) Data Collection - Consists of means to scan the transducers for the basic data and transfer it to the on-line computer in a form digestible to the computer's input channel. The basic intelligence is composed of analog and bilevel signals.
- 2) Data Storage - Consists of long term retention of data converted and packed on a RAD or magnetic tape.
- 3) Data Retrieval - Consists of means of retrieving stored data from RAD's and/or magnetic tape for use in computing LSS trends, LSS performance, and fault analysis

#### Task 2. Data Reductions

##### Subtasks:

- 1) Off-Line Data Reduction - Provides long term evaluation of data. Examples of uses are: (1) LSS trend analysis, (2) LSS performance analysis, and (3) Crew performance.
- 2) On-Line Data Reduction - Real time processing and evaluation of data being input to the computer. Example of uses are: (1) Fault isolation, (2) automatic control, and (3) status monitoring and alarm.

#### Task 3. Display and Control

##### Subtasks:

- 1) "Quick Look" Capability - Ability to permit examination of a parameter at will. Request would be made at keyboard with display on a CRT in engineering units.

- 2) Monitor and Alarm - Ability to scan selected critical channels and notify the test conductor when preset limits are exceeded. This must permit flexible selection of limits and channels to be monitored.
- 3) Fault Isolation - Use of a programmed analysis procedure to pinpoint the component problem. The programs used for this effort would be callable by the crew or staff.
- 4) Hard Copy Capability - Ability to request a printout of all or selected processed data in the test operations area.

Task 4. Automatic Control - This task should be considered as an experiment during both Phase A and Phase B testing. It is discussed in Section 3.3.5.

### 3.8.3 Data System Equipment Trade-Off

Figure 20 shows three hardware options which will provide some level of capability in performing the general tasks discussed in the previous section. Each option offers increased sophistication in rapid data retrieval, processing, storage and display. A brief discussion of each option is covered below.

#### Option 1

Test Phase A - This consists of the same hardware that was used for the 90-day test. No data retrieval, on-line data reduction, and "quick look" capability or on-line fault isolation would be possible. Off-line calculation, however, would be possible.

Test Phase B - An unrestricted time share terminal would be used to replace the data link shown in Phase A. An unsophisticated approach to much of the on-line requirements would be possible with this equipment.

#### Option 2

Test Phase A - This would offer the same capability as that shown for Option 1 Test Phase B.

Test Phase B - A dedicated computer (full time) would be utilized for data management. It would provide the on-line real time capability required to properly monitor and evaluate the overall aspects of the test.

FIGURE 20. INFORMATION MANAGEMENT SYSTEM OPTIONS

OPTION	[TEST A] [TEST B]	DATA LINK BATCH UNRESTRICTED TIME SHARE BATCH	EC/LS						CREW INFORMATION MANAGEMENT	MISSION SIMULATION	BIO- MEDICAL	BEHAVIOR	PROCEDURE	COMMENTS	
			SYSTEM STATUS	SYSTEM PERFORMANCE	TREND ANALYSIS	FAULT ISOLATION	AUTOMATIC CONTROL								
OPTION 1	[TEST A]	DATA LINK	*YES W/ NO DELAY	1 DAY DELAY	1 DAY DELAY	1 DAY DELAY	1 DAY DELAY	NONE	LIMITED	NO	LIMITED	LIMITED	NO	LIMITED	SIMILAR TO SYSTEM USED ON 90 DAY TEST
									NO					YES	
	[TEST B]	BATCH	*YES W/ NO DELAY	LIMITED W/ NO DELAY	LIMITED W/ NO DELAY	1 DAY DELAY	1 DAY DELAY	NONE	YES	LIMITED	YES	LIMITED	YES	YES	UTILIZES OUTSIDE COMPUTER
									NO					NO	
OPTION 2	[TEST A]	UNRESTRICTED TIME SHARE	*YES W/ NO DELAY	LIMITED W/ NO DELAY	LIMITED W/ NO DELAY	1 DAY DELAY	1 DAY DELAY	NONE	YES	LIMITED	YES	LIMITED	YES	YES	-
									NO					NO	
	[TEST B]	DEDICATED COMPUTER	YES W/ NO DELAY	YES W/ NO DELAY	YES W/ NO DELAY	YES W/ NO DELAY	YES W/ NO DELAY	YES LIMITED BY COMPUTER SIZE	YES	YES	YES	YES ASSUME INTERNAL CAPABILITY	YES	YES	-
									NO					NO	
OPTION 3	[TEST A]	DEDICATED COMPUTER	YES W/ NO DELAY	YES W/ NO DELAY	YES W/ NO DELAY	YES W/ NO DELAY	YES W/ NO DELAY	YES LIMITED BY COMPUTER SIZE	YES	YES	YES	YES ASSUME INTERNAL CAPABILITY	YES	YES	SOFTWARE INCORPORATED INCREASED SCOPE OVER OPTION 3-1
									NO					NO	
	[TEST B]	DEDICATED COMPUTER	YES W/ NO DELAY	YES W/ NO DELAY	YES W/ NO DELAY	YES W/ NO DELAY	YES W/ NO DELAY	YES LIMITED BY COMPUTER SIZE	YES	YES	YES	YES ASSUME INTERNAL CAPABILITY	YES	YES	-
									NO					NO	

• Using the CDC  
3090 Computer

### Option 3

Test Phase A and Test Phase B - This option calls for both tests to operate with a dedicated computer. All system tasks could be performed.

#### 3.8.4 Data Management System Specifications

Specifications were developed for the Phase A test. The Phase B test will encompass the same tasks and will require additional channels. Phase B specifications will be developed based on findings during the Phase A test. The specifications for Phase A are as follows:

##### 1. Data Collection

###### a. Life Support System Input Data

270 Analog Channels

150 Bi-Level Channels

###### b. Behavioral Input Data

50 Analog Channels

###### c. Bio-Medical Input Data

50 Analog Channels

##### 2. Data Reductions

###### a. Real Time

- (1) System Status - 50 channels of input data are required to be available at the CRT. This data is needed in engineering units, but has not been processed by any algorithm.
- (2) System Performance - Twelve (12) systems would be monitored. This data would be processed and displayed on the CRT's.
- (3) Monitor/Alarm - 70 channels will be monitored for safety purposes and incipient subsystem failure. The method of display will depend on the display mechanization.

b. Off-Line

- (1) Time History - A time history of the data collected would be kept by converting raw data to engineering units and storing it on tape. Periodically, the tape would be put on an off-line computer for high speed printing.
- (2) Trend Analysis - Certain data would be processed by algorithms to allow trends to be analyzed. An example is to determine if normal system degradation requires resetting limits on the monitor/alarm system. The numerical requirements will be determined during program development.
- (3) Fault Isolation - A diagnostic program is required to analyze data from 200 channels and signal out-of-tolerance conditions.

3. Manual Data Input

It is required that certain data be input by the crew through a keyboard. Inputs will be data relating to mass balance, food, inventories, behavioral and request (i.e., CALL UP) for specific subroutines.

4. Displays

A unified display, at the Test Control station, is necessary to have maximum efficiency and flexibility. A split screen capability for the CRT at that station would provide such a capability. The data system must utilize higher level language in order to provide a reasonable utility and future improvement potential.

There are several related programs which influence the choice of a computer for the Phase A and B tests. One is the CVT program at NASA, MSFC, which will use an XDS 930 during initial phases as part of the Information Management System. NASA is now producing software specifications for this program. The advantages of using a similar system for the Phase A and B tests is obvious if it permits exchange of information and shared development of the required software. The CVT software specifications will include a Real Time



Executive, higher level languages, and other control programs. If these can be used on an XDS-930 during the Phase A test, a substantial reduction in cost would be realized and the realism of the simulation would be improved.

### 3.8.5 System Definition

In reviewing the above discussions and implementing the specifications, it is found that emphasis must be placed upon implementing Option 3 of Section 3.8.3. If economic limitations do not allow this approach, and it is necessary to accept Option 2, a very limited capability for monitor and alarm functions and virtually no on-line data display will be possible.

The major requirement in implementing Option 3 is the availability of an on-line computer continuously during the test period, and for a pre-test period sufficient to accomplish the all-systems checkout as well as program de-bugging. Assuming the availability of such a computer and the required peripheral and support devices, it is necessary to accomplish software development with the intention of building up in level of sophistication through the Phase A and Phase B programs.

The data collection and management system similar to that shown in Figure 21 is recommended for the future extended manned tests, and is described in Section 11 of the Preliminary Test Plan CR-111999.

The system illustrated in Figure 21 is presently in operation at the MDAC facility in Huntington Beach. In order to show the functional requirements for data management, a description is provided herein. The system features an XDS 930 remotely located in a nearby building and hardwired for on-line capability to the test control area. Suitable intercom units are available for two-way transmission of data. A CDC 8090 computer is also used for data collection, monitoring, and automatic shutdown control of equipment under test. It is proposed, for extended manned tests, to limit its function to monitor and alarm of the 70 critical channels mentioned above. In this function it unloads the XDS 930 and allows it to concentrate on data collection, reduction and display functions. The capacity of the CDC 8090 is much less than required for the complete data management system.

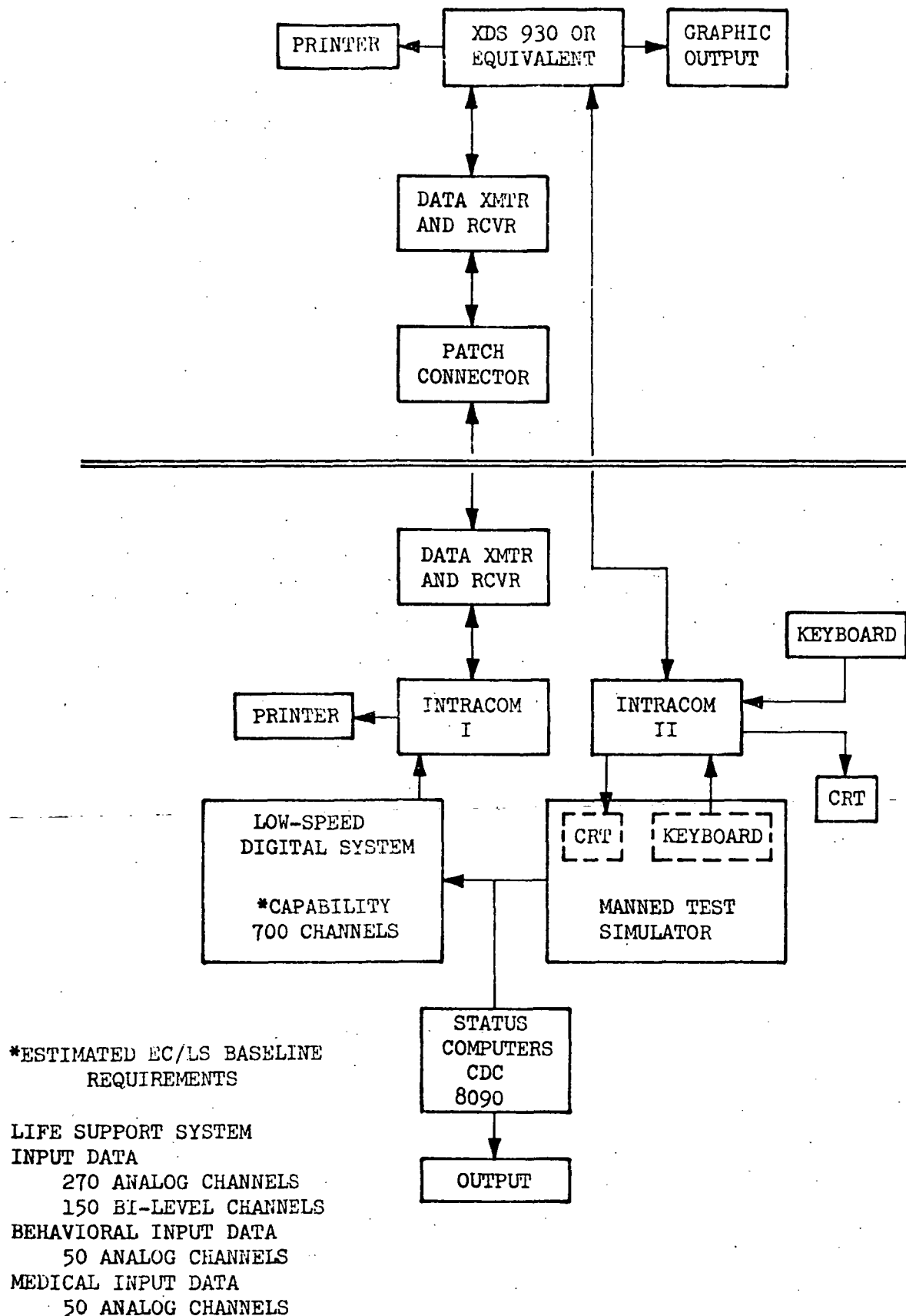


FIGURE 21. INFORMATION SYSTEM EQUIPMENT SCHEMATIC

As mentioned above, use of the XDS 930 as recommended enables the use of common programs previously developed. Section 11.2 of the Preliminary Test Plan NASA CR-111999 lists programming requirements, noting those that are existing and new developments required. The "existing" programs are generally based upon those under development for the CVT at NASA MSFC. The use of the G189 Life Support System Design Program is not contemplated, although some adaptation of subroutines of this program as algorithms for automatic control or trend analysis is possible.

### 3.8.6 Conclusion

A dedicated computer is required to provide the advanced capability needed in the Phase A test. Broad experience can be obtained utilizing real time on-line data processing. In addition a reduction in man hour requirements during the test will allow a definite cost savings. This is possible due to the indepth trend analysis, system status, system performance, and fault isolation.

## Section 4

### CONCLUSIONS AND RECOMMENDATIONS

This study has shown that extended manned testing of regenerative life support systems can produce valuable data on the comparative performance of advanced prototype processes which can be used by system designers.

It has been determined that two tests can be performed for evaluation of alternate equipment presently in the prototype design or fabrication phases. The first test (Phase A) is recommended for a four week duration late in 1972 to evaluate a group of advanced subsystems using baseline equipment available from previous manned tests. The second test (Phase B) features evaluation of a second group of advanced subsystems and uses improved versions of the advanced subsystems from the Phase A test as backup. Complete evaluation of these subsystems will require a 9-week test and is recommended for late in 1973. It is expected that more efficient processes presently in conceptual phases and others to be developed in the future will indicate the requirement for subsequent extended manned tests.

In addition to evaluation of advanced subsystems it is recommended that the planned tests should feature progressively increasing sophistication in centralized automatic monitor and alarm, fault isolation, and system automation in order to achieve a closer approximation to realistic future systems operation. Also, these tests are planned to provide the opportunity to incorporate medical and behavioral investigations which provide data that could not be economically obtained in any other way, and which provide crew activity levels necessary to achieve a realistic operational simulation that ensures the application of realistic loads to the life support system.

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Appendix A  
EXPERIMENTAL DESIGN AND COMPUTER ANALYSES OF BIOMEDICAL  
BLOOD AND URINE SAMPLE COLLECTION

Introduction

The objective of the experimental design and computer analysis is to provide a maximum amount of information to assist in the initial examination of the results of the blood and urine sample collection. In general, clinical symptomatology and medical legal considerations are assumed to be the motivation for the blood and urine tests. Diurnal recycling is also of interest.

From an experimental design point of view, the null hypothesis states there will be no significant changes in the results of the blood and urine tests due to the crewmen being exposed to test conditions.

The 90-day test demonstrated the advisability of using computer programs for the analyses of blood and urine tests. Computer programs have the capability of performing very rapid calculations requiring no human intervention beyond the setting up of the input deck and providing inexpensive analyses. Furthermore, many iterations to investigate particular areas of interest are possible using computer analyses.

Formatting the data for computer runs requires some preparation. However, if sufficient forethought is given to the procedure for collecting the input data, this time can be minimized. The results of the blood and urine tests can be entered directly onto load sheets from which punched cards can be generated. These load sheets can double as the permanent record of the blood and urine test results. It is critically important to coordinate with the Systems Analyst and/or the Programmer involved with designing the load sheet format.

Tests To Be Performed

Blood tests and urine tests are to be performed on the samples collected before, during, and after the 4-week manned test. Under the heading of blood tests, there are two subparts. They are Hematology and Biochemistries. Table 1 details these tests. They represent the minimum number of tests to be performed and by no means represent the final list. It will be noticed that the

Table 1  
BIOMEDICAL ANALYSIS OF BLOOD AND URINE  
TESTS TO BE PERFORMED

Blood Tests

A. Hematology (venous or cutaneous sample)

1. Hemoglobin
2. Microhematocrit
3. White Blood Cell Count
4. Red Blood Cell Count

B. Biochemistries - SMA-12 (10cc venous sample frozen for later analysis)

1. Alkaline Phosphatase
2. Bilirubin Total
3. Uric Acid
4. SGOT
5. LDH
6.  $Ca^{++}$
7. Inorganic Phosphorus
8. Total Protein
9. Albumin
10. Blood Urea Nitrogen
11. Glucose
12. Cholesterol
13. Albumin/Globulin

Urine Tests

Test for: (single sample or total urine volume for 24 hours)

1.  $Na^{+}$
2.  $K^{+}$
3.  $Cl^{-}$
4.  $Ca^{++}$
5.  $PO_4$
6. Specific Gravity
7. Titratable Acidity
8.  $H^{+}$
9.  $NH_3$
10. ph



biochemistry test #13 is actually a ratio which is calculated from several previous tests; this calculation will be performed as the first step of the data analysis.

The ten urine tests are also called out in Table 1. These tests are performed on a single sample of the total urine volume for 24 hours.

#### Schedule of Sample Collection

For purposes of the biomedical analysis of blood and urine, the test period consists of a pre-manned test period, the manned test itself, and a post-manned test period. Each of these periods will be 28 days, or 4 weeks in length. The blood will be collected by means of venous sampling techniques during the three test periods, with one sample being collected each week.

For the urine analysis, a daily aliquot from the entire 24-hour output of each crewman will be used. The urine samples will be collected two weeks immediately prior to the manned test, during the entire manned test, and two weeks after the manned test.

Table 2 shows the schedule of sample collection for both the blood and the urine as it is presently planned.

There appears to be some doubt as to the optimum frequency of collection of blood samples. In order to determine what this frequency should be, a pilot experiment (not shown in Table 2) might be employed. This experiment would precede the pre-manned test period and would be designed such that blood would be collected every day for two or three samples a day. It is not necessary that crewmen be used in this pilot experiment; men of comparable age and stature would suffice. The results of the blood tests performed on the pilot experiment subjects would give an indication as to the kind of variation to be expected in the crewmen and would thus permit the best educated guess as to the optimum frequency of sample collection.

TABLE 2  
BIOMEDICAL ANALYSIS OF BLOOD & URINE  
SCHEDULE OF SAMPLE COLLECTION

		PRE MANNED TEST																											
DAY →		0	2	4	6	8	10	12	14	16	18	20	22	24	26	28													
		WK 1					WK 2					WK 3					WK 4												
<u>BLOOD</u> (10cc Venous Sample)	8am		x		x		x		x		x		x		x		x		x										
	4pm		x		x		x		x		x		x		x		x		x										
<u>URINE</u> (Sample of 24-hr Collection)												x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
		Once/Day																											

		MANNED TEST																											
DAY →		0	2	4	6	8	10	12	14	16	18	20	22	24	26	28													
		WK 1					WK 2					WK 3					WK 4												
<u>BLOOD</u> (10cc Venous Sample)	8am		x				x			x				x			x												
	4pm		x				x			x				x			x												
<u>URINE</u> (Sample of 24-hr Collection)			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
		Once/Day																											

		POST MANNED TEST																											
DAY →		0	2	4	6	8	10	12	14	16	18	20	22	24	26	28													
		WK 1					WK 2					WK 3					WK 4												
<u>BLOOD</u> (10cc Venous Sample)	8am		x		x		x		x		x		x		x		x		x										
	4pm		x		x		x		x		x		x		x		x		x										
<u>URINE</u> (Sample of 24-hr Collection)			x	x	x	x	x	x	x	x	x	x	x	x	x	x													
		Once/Day																											

x = Sample Collection

## Experimental Design for the Analysis of Blood Tests

The analysis of the blood tests will follow a 4-part procedure (illustrated in Table 3). The first operation to be performed on the raw data will be the pre-processing of the raw data. This will consist of the normalization of the data to accommodate the crewman body size if this is desirable for the specific blood test. Also, ratios of selected blood test scores can be constructed at this point. The second step in the analysis of the blood samples consists of computer-drawn plots of the preprocessed raw data. For 17 tests, 4 hematology tests and 13 biochemistry tests, 136 plots would be generated for 8 crewmen. The plots will enable the biomedical investigators to see unusual patterns in the raw data and to generate hypotheses about the interactions and causal effects of the manned test on the blood constituents. The axis of the plots will be the value of the test results, and the horizontal will be the collection day.

The third part of the experimental design consists of initial multiple correlations of the blood test results. These correlations permit the examination of patterns between the individual blood tests in order to determine which constituent varies with what other constituent. These correlations are thought of as initial correlations, with other correlations to be run based on the interpretation of the results of these initial computer runs. Since there are four ways in which the crewmen can be combined, that is, all eight crewmen, the inside and outside crew, the day/night divisions of the inside crew, and the total crew, by the four test periods, there are 16 total computer runs to be made.

A by-product of the multiple correlations is the descriptive statistics provided by the correlation program. These statistics consist of the mean value of each set of the test scores, the standard deviation of these values, and the range. These statistics should be quite helpful in the preliminary investigation of the results of the blood tests.

The fourth part of the experimental analyses consists of the initial analysis of variance. This design is illustrated in Table 3. Analysis of variance designs requires a factorial experimental design; a 4-dimensional factorial design is used. The four dimensions are: blood tests (hematology and biochemistries);

Table 3  
BIOMEDICAL ANALYSIS OF BLOOD AND URINE  
EXPERIMENTAL DESIGNS FOR ANALYSIS OF BLOOD TESTS

1. Preprocessing of Raw Data
  - A. Normalization (if desirable)
  - B. Ratio Construction
2. Computer Plots of Preprocessed Raw Data and Ratios
  - A. 17 tests x 8 crewmen = 136 plots
  - B. Plots are: test results by sample collected
3. Initial Multiple Correlation of Blood Test Results
  - A. Number of Computer Runs = 16

Tests<sub>17</sub> x CM<sub>8</sub>  
 Tests<sub>17</sub> x Inside/Outside CM<sub>2</sub>  
 Tests<sub>17</sub> x Day/Nite Inside CM<sub>2</sub>  
 Tests<sub>17</sub> x Crew

PRE	MANNED TEST	POST	ENTIRE

Each elem represents one computer run

- B. Statistics provided by correlation program for each run
  - 1) mean value of test sample
  - 2) standard deviation
  - 3) range

4. Initial Analysis of Variance Design

- A. Tests x CM x Manned Test Period x Collection Time (one computer run)

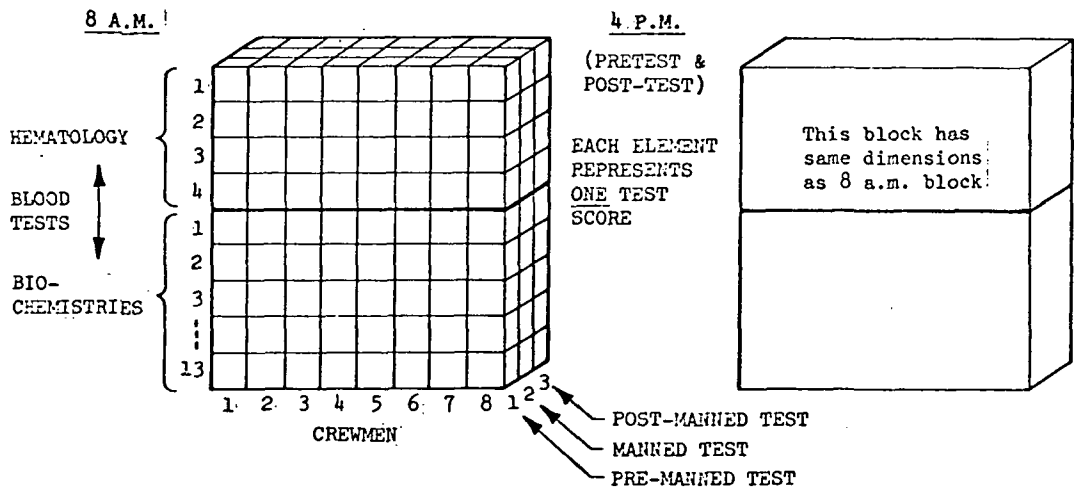
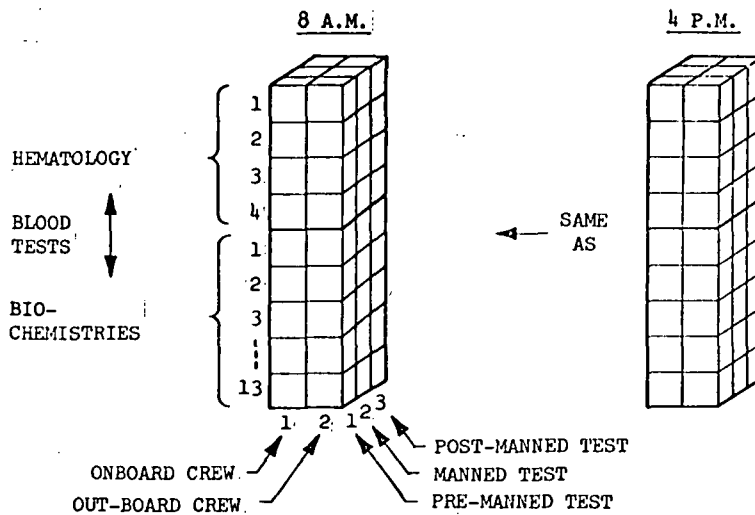


Table 3 (Continued)

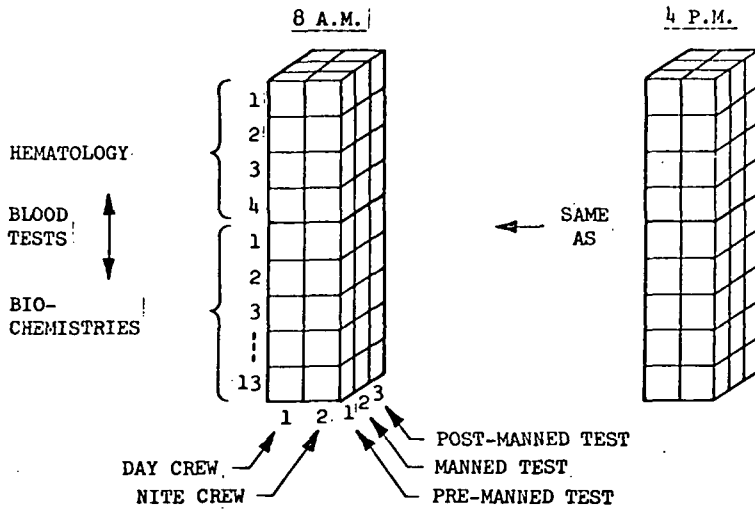
EXPERIMENTAL DESIGN FOR ANALYSIS OF BLOOD TESTS

h. Initial Analysis of Variance Design (Continued)

B. Tests x On-Out CM x Manned Test Period x Collection Time (one run)



C. Tests x Day-Nite CM x Manned Test Period x Collection Time (one run)



crewmembers, eight in this design; period of the manned test; and time of day of collection. This single, 4-dimensional design represents one computer run, unless it is judged that the hematology and blood chemistries should be run separately. If this is the case, two computer runs will be necessary.

The second and third analysis of variance designs are also shown in Table 3 and are quite similar to the first design with the difference that in the second design the outboard crew and the onboard crew constitute the crew breakdown. In the last design, the day crew and the night crew constitute the crew breakdown of only the onboard crew. The remaining dimensions for these designs are the same as for the initial design explained. The comment about the possibility of the hematology and the biochemistries being two runs applies here also.

#### Experimental Design for Analysis of Urine Tests

The design for the urine tests follows, in general, the experimental design for the blood tests. The four subparts to the design (shown in Table 4) follow the four subparts mentioned above.

The first operation to be performed on the raw data, the scores of the tests, is the preprocessing step. This consists of normalization of the urine scores to body weight, as well as ratio construction of more complex indices of urine results.

Computer plots of the preprocessed raw data and ratios are the next item in the biomedical analysis of the urine tests. Eighty plots, computer generated, result from 10 urine tests of 8 crewmembers. The plots are test results on the vertical axis, vs the day of the sample collected on the horizontal axis.

The initial multiple correlations of the urine test results follow the same pattern as the blood test correlation. Four types of combinations of crewmembers by the four periods to be examined give 16 computer runs to generate the correlations. As before, descriptive statistics are provided by the correlation program for each of the 16 runs.

Table 4  
BIOMEDICAL ANALYSIS OF BLOOD AND URINE  
EXPERIMENTAL DESIGN FOR ANALYSIS OF URINE TESTS

1. Preprocessing of Raw Data
  - A. Normalization to Body Weight
  - B. Ratio Construction
2. Computer Plots of Preprocessed Raw Data and Ratios
  - A. 10 Tests x 8 Crewmen = 80 plots
  - B. Plots: Test Results by Sample Collected
3. Initial Multiple Correlations of Urine Test Results
  - A. Number of Computer Runs = 16

Tests<sub>10</sub> x CM<sub>8</sub>  
 Tests<sub>10</sub> x Inside/Outside CM<sub>2</sub>  
 Tests<sub>10</sub> x Day/Nite Inside CM<sub>2</sub>  
 Tests<sub>10</sub> x Crew<sub>1</sub>

PRE	MANNED TEST	POST	ENTIRE

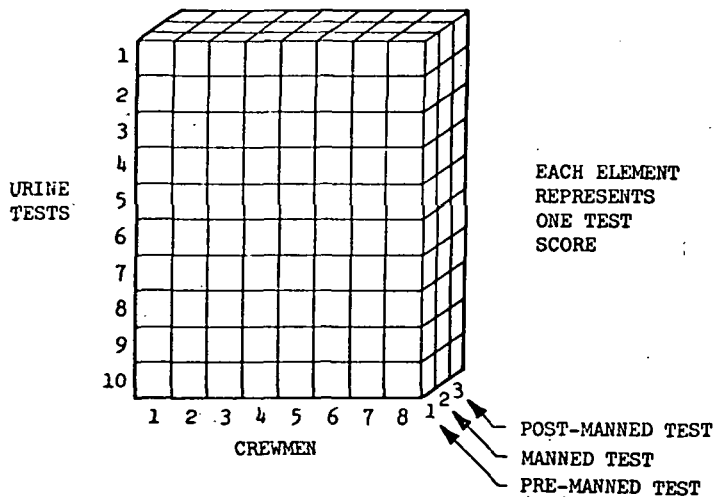
EACH ELEMENT REPRESENTS ONE COMPUTER RUN.

- B. Statistics Provided by Correlation Program for Each Run

- 1) Mean value of test sample
- 2) Standard deviation
- 3) Range

4. Initial Analysis of Variance Design

- A. Tests x CM x Manned Test Period x Collection Time (one computer run)



The initial analysis of variance design is shown in Table 4. This is a 3-dimensional design with the results of urine tests, crewmen, and the manned test period providing the three dimensions. Each element in this design represents one test score, and the entire design is one computer run.

#### Concluding Remarks

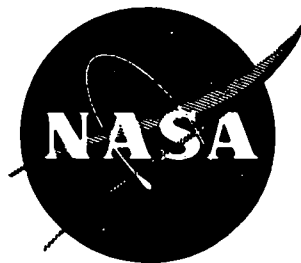
The purpose of this Appendix is to explain an experimental design which yields the maximum information on the test scores for the blood and urine sample collection. Hopefully, it will be found that the null hypothesis cannot be accepted because of significant differences and pattern deviations showing up in the analyses. If this is the case, other analyses will have to be performed to further investigate the detailed discrepancies found in the data. The results of the initial analyses are a prerequisite to the design of these other and more interesting analyses.



## **PRELIMINARY TEST PLAN**

# **DEFINITION STUDY FOR AN EXTENDED MANNED TEST OF A REGENERATIVE LIFE SUPPORT SYSTEM**

**November 1971**



**Prepared under Contract No. NAS1-10790  
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